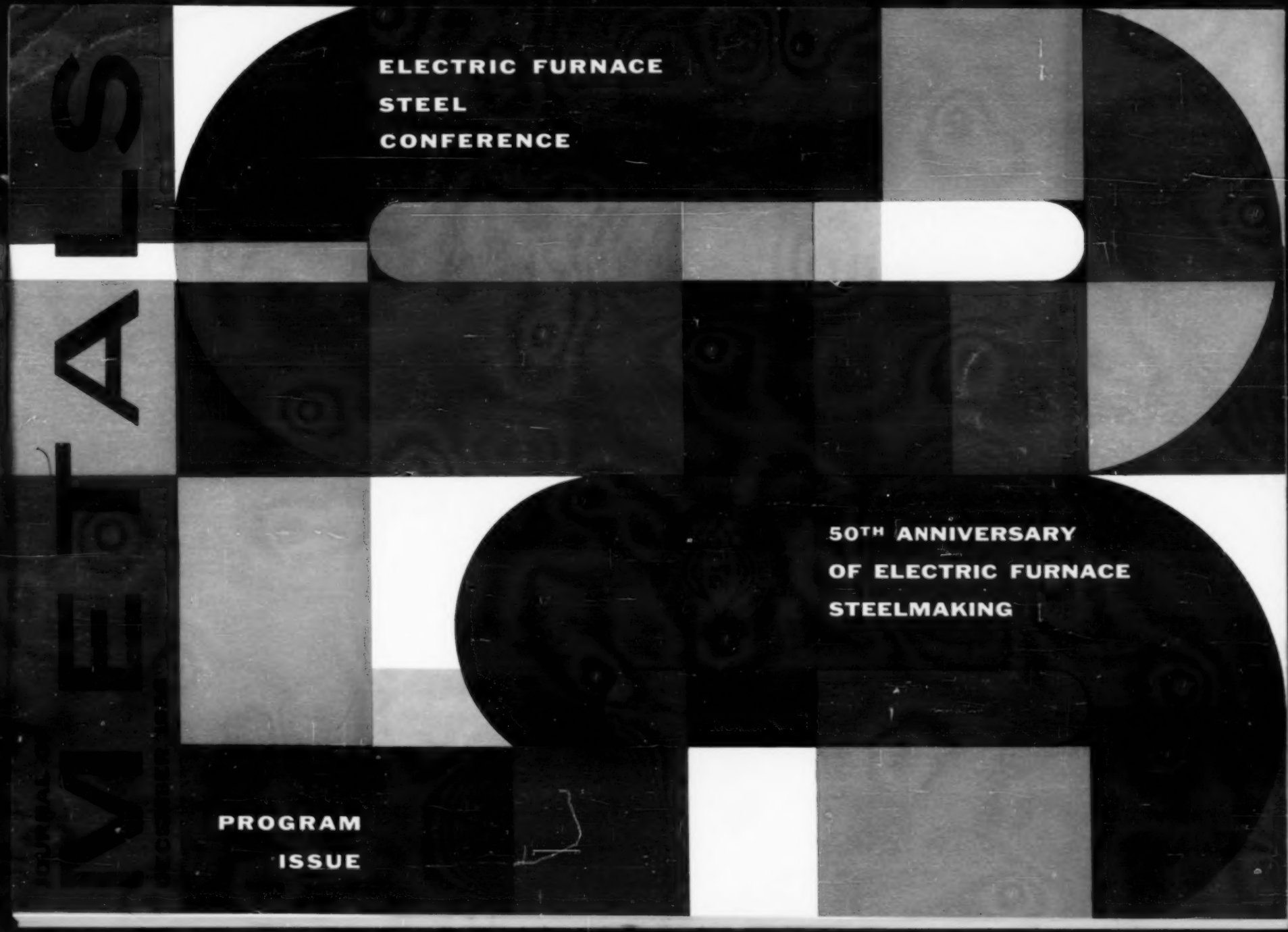
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VOL. 8, NO. 12

DECEMBER 1956

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COVER

JOURNAL OF METALS congratulates the electric furnace steelmakers on the occasion of their fiftieth anniversary. We are expecting even greater progress in the industry's second half-century, turn to p. 1637 . . . artist Harry Brocke.

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(Continued on page 1612)

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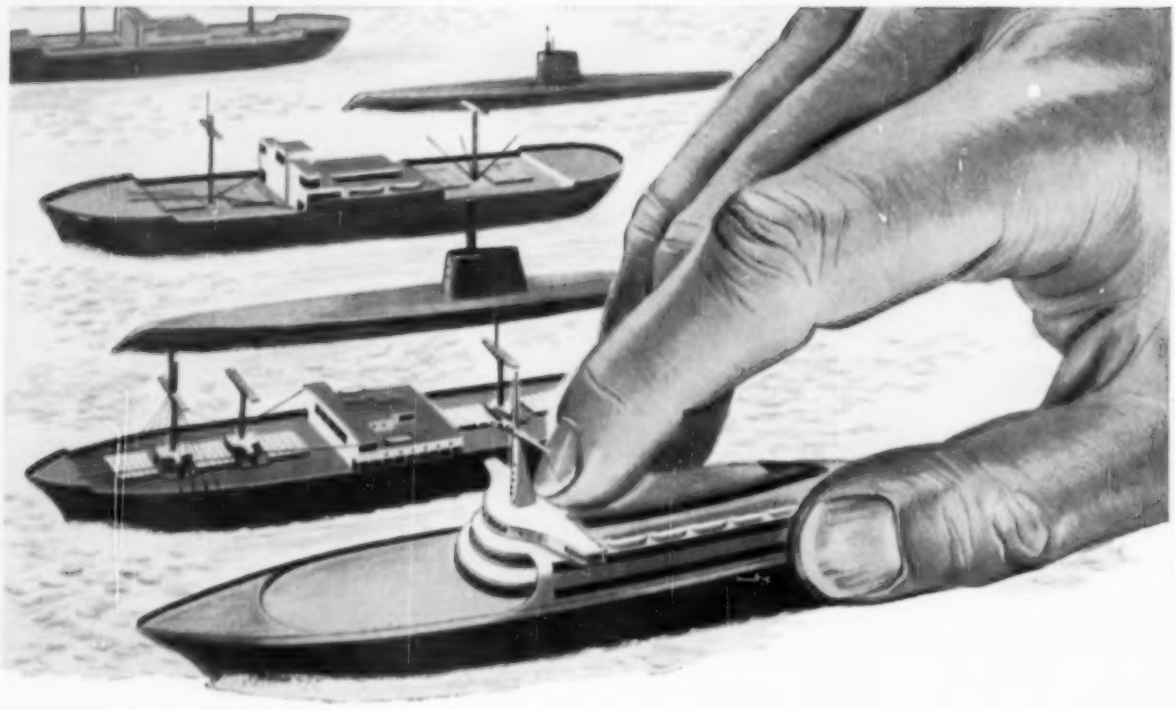

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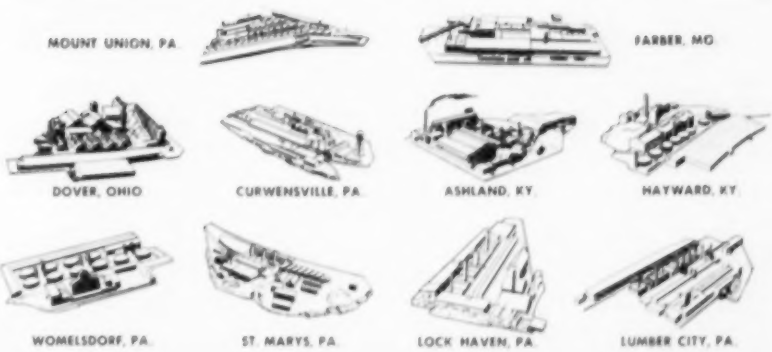

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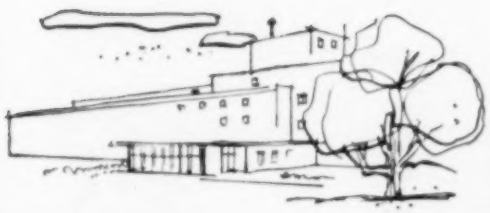

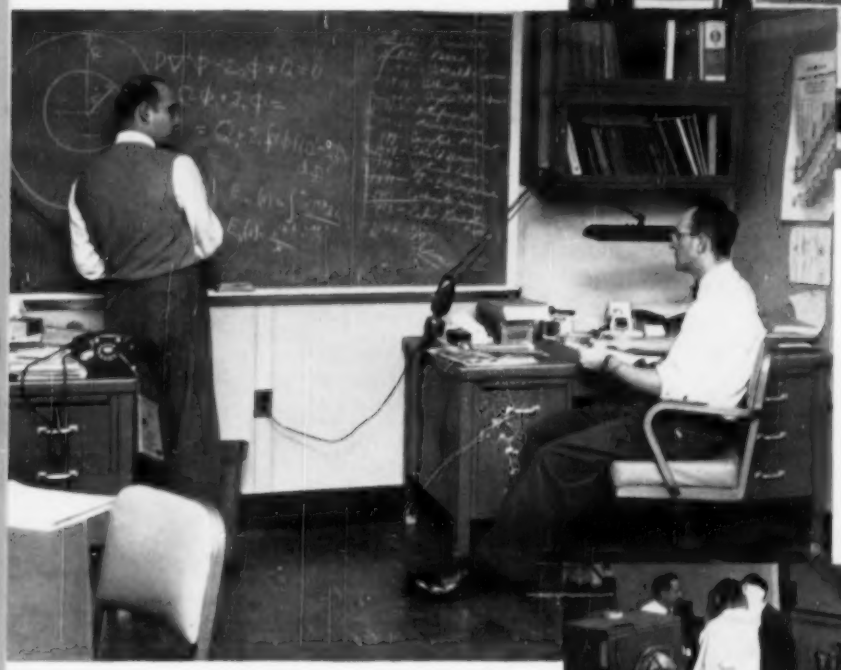

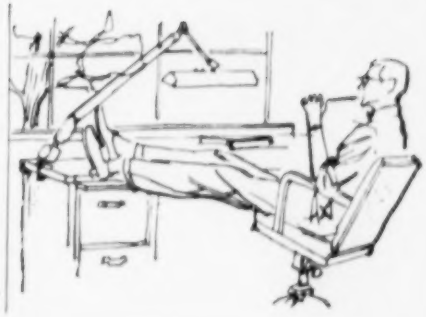

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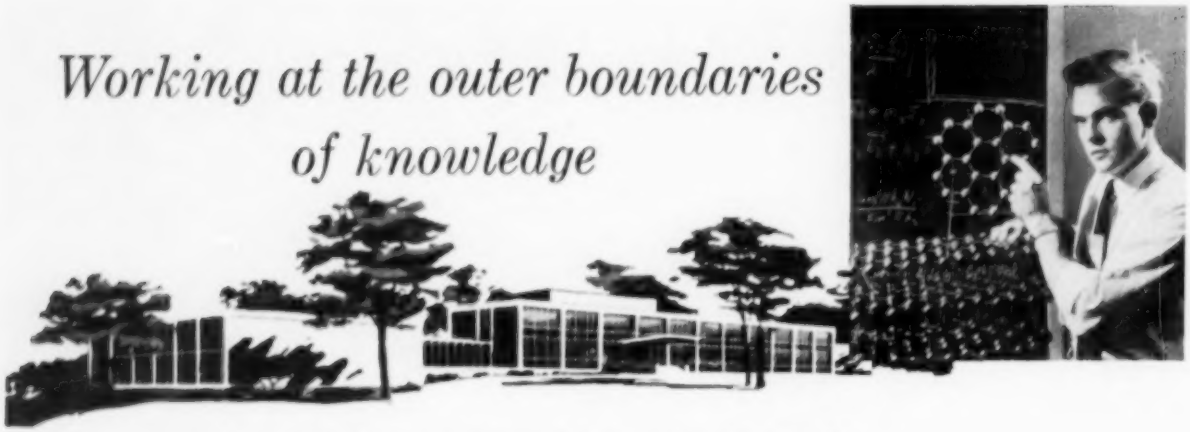
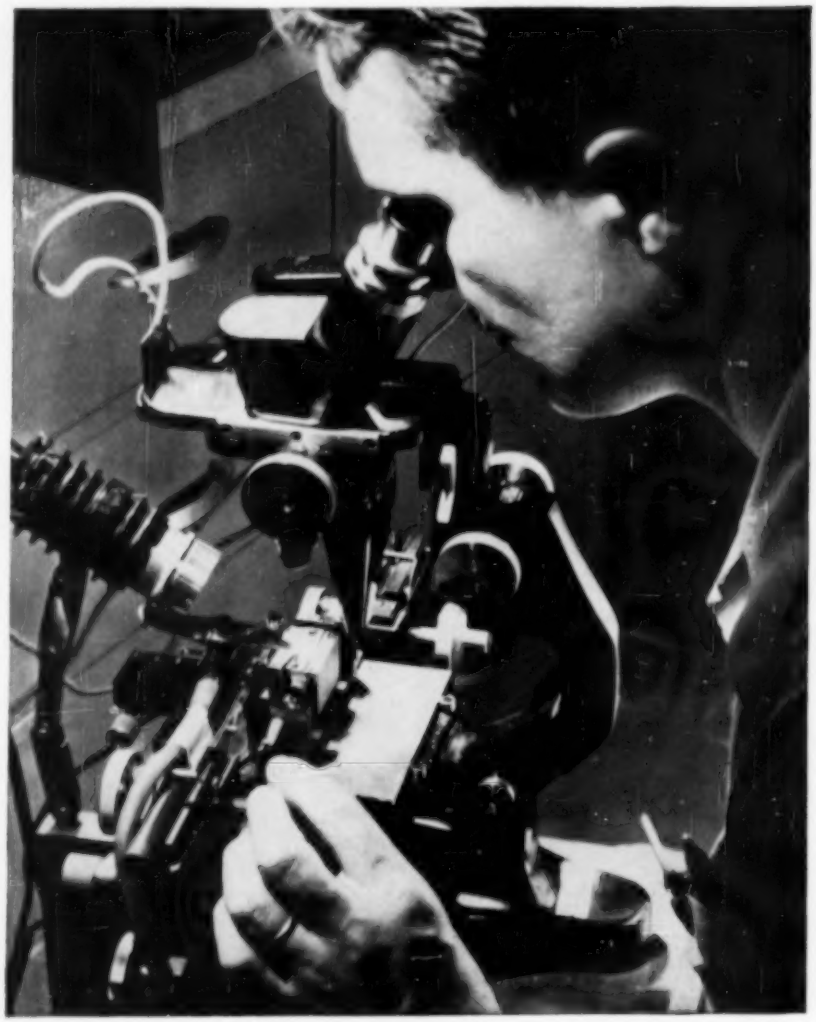
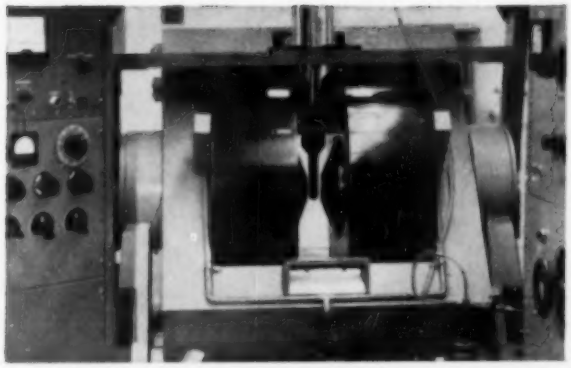


New Research Laboratories in Parma, Ohio. To expand its pioneering work in solid state and chemical physics, National Carbon Company has enlarged its staff of scientists and provided them with an ideal laboratory setup for creative work. Typical of their modern experimental equipment is an *arc radiation furnace* used for work on high-temperature refractories. It can bring light from a carbon arc into focus on a tiny pin-point area, *achieving an intensity* of several hundred million foot-candles — *approaching the intensity of light near the surface of the sun.*

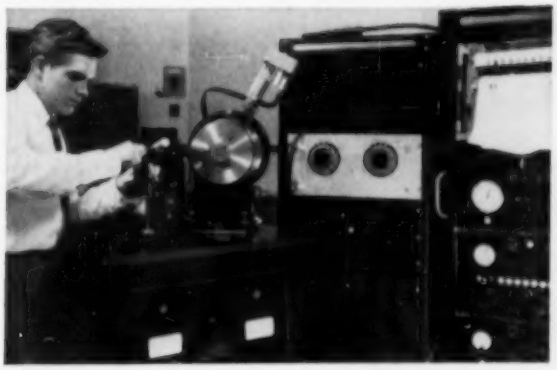
New



Mechanized tweezers handle graphite crystal. To make it into a proper experimental guinea pig, the fragile crystal must be painstakingly cut and mounted so that electrical flow can be measured along the unique crystalline directions in graphite. Experiments with pure crystals are important because all materials which we know as carbon and graphite are basically composed of the same graphite crystals being prepared here. Tremendous differences in electrical behavior and other vital properties can be traced to variations in size and arrangement of the graphite crystals in carbon products.



Graphite must pass good-conduct test. A tiny graphite crystal is chilled to within one degree of absolute zero, then held between poles of a powerful electromagnet, while electrical conductivity is measured in each crystalline direction — one of many ways to learn more about carbon.



X-ray "scatter" test reveals secrets of graphite. Testing the x-ray diffraction of carbon and graphite samples gives researchers a picture of relationships between crystals in carbon and graphite materials. This is another experimental method for probing the mysteries of carbon.

break-through in carbon physics research

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This barrier—the inability to get large graphite crystals pure enough for experimental needs – has now been overcome by researchers of National Carbon Company. Their new annealing techniques, which remove impurities from large graphite crystals, also eliminate imperfections and weaknesses in the crystalline structure.

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BOOKS

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Surveys in Mechanics, edited by G. K. Batchelor and R. M. Davies, *Cambridge University Press,* $9.50, 475 pp., 1956.—Ten monographs on various aspects of mechanics are collected in this volume as a tribute to Sir Geoffrey I. Taylor on his seventieth birthday. Papers on the mechanics of quasi-static plastic deformation in metals, dislocations in crystalline solids, and stress waves in solids are included.

Chromium, Vol. I, **Chemistry of Chromium and its Compounds,** edited by Marvin J. Udy, *Reinhold Publishing Corp.,* $11.00, 421 pp., 1956.—This is the first of a two volume monograph on the sources, properties, manufacture and use of metallic chromium and chromium alloys, written by 30 experts and edited by Dr. Udy. Sections on the recovery of the metal from its ores and its use in steels and nonferrous alloys are of particular interest to metallurgists.

Panel Discussion on Pyrometric Practices, *American Society for Testing Materials,* $1.50, 41 pp., 1956.—This discussion is concerned with ASTM recommended practices on high-temperature testing of metals, E 21, E 22, and E 85, with emphasis on defining the precision of temperature measurement and control.

1955 Book of Standards, *ASTM,* 1956. **Part I: Ferrous Metals,** $13.50, 1834 pp.—This part contains 315 standards, 211 of which are new or revised, on the steels, both carbon and alloy; irons; ferro-alloys; and numerous tests. **Part II: Non-Ferrous Metals,** $11.00, 1516 pp.—Of the 270 standards in this part, which covers coppers, leads, aluminum, magnesium, and metal powders, 156 are new or post-1952 revisions.

ASTM Standards on Copper and Copper Alloys, *ASTM,* $5.75, 654 pp., 1956.—This volume incorporates handily all ASTM standards developed by Committees B-5 on Copper and Copper Alloys, B-1 on Wires for Electrical Conductors, and B-2 on Non-Ferrous Metals and Alloys. Fifty of the specifications have been revised since the previous edition, and a new one for threadless copper pipe has been added.

Symposium on Atmospheric Corrosion of Non-Ferrous Metals, *ASTM,* $2.75, 164 pp., 1956.—This work offers the results of exposure tests begun 27 years ago by Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, utilizing 24 wrought alloys of zinc, nickel, copper, lead, tin, and aluminum. The test report lists all data gleaned from 9000 test specimens, and nine papers discuss in detail the significance of the results in each field.

Minerals for Atomic Energy, by Robert D. Nininger. *D. Van Nostrand Co., Inc.* $8.00, 380 pp., 1956.—Revised edition of a complete handbook on prospecting for atomic energy minerals. Part I describes the minerals and mineral deposits that are sources and potential sources of uranium, thorium, and beryllium. Part II is a comprehensive survey of the various areas of the world with respect to their favorability for new deposits of atomic energy minerals. Part III covers prospecting equipment and techniques.

Specifications and Tests for Electrodeposited Metallic Coatings, *ASTM,* $1.85, 92 pp., 1955.—This is a concise presentation of specifications, testing methods, and recommended practices for electrodepositing metallic coatings.

Elementary Crystallography, by M. J. Buerger, *John Wiley & Sons,* $8.75, 524 pp., 1956.—An introduction to the fundamental features of crystals, this text is designed to provide a solid foundation in crystallographic theory and the symmetry properties of crystals.

Symposium on Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures, *ASTM,* $2.75, 120 pp., 1956.—A collection of papers on oxidation and surface effects and on creep under controlled atmospheres.

(Continued on page 1612)

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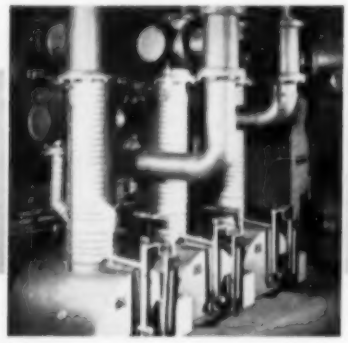
Compact, self-contained Stokes Vacuum Furnace is being used for investigations of vacuum melting of high temperature alloys, at International Nickel Company, Inc., Bayonne, New Jersey.

THE METALS INDUSTRY IS PROFITING FROM THE USE OF OTHER STOKES PRODUCTION EQUIPMENT



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Exclude air and remove gases from metals, and you can create extra properties of strength and endurance that are unattainable by conventional techniques. This is one of the promising lines of metallurgical development that International Nickel Company, Inc. is investigating in their laboratories at Bayonne, New Jersey.

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REFERENCE DATA: Vacuum Furnaces—Catalog 790 • Microvac Pumps—Catalog 752 • Diffusion and Booster Pumps—Specification and Performance Data • Story of the Ring-Jet Pump—Booklet 756 • How to Care for Your Vacuum Pump—Booklet 755 • Vacuum Metallizing—Catalog 780 • Vacuum Calculator Slide Rule • Powder Metallurgy Today • Powder Metal Presses—Catalog 815

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STOKES

Books

(Continued from page 1608)

Please Order These Publications from the Publishers

Year Book for 1955, *American Bureau of Metal Statistics,* 50 Broadway, N. Y. C., $3.00 postpaid, 127 pp., 1956.—Production, consumption, and operating statistics of lead, copper, zinc, aluminum, gold, silver, and other metals are included in addition to tables of metal prices, lists of metallurgical plants and capacities.

Zirconium—Technology and Economics, *Atomic Industrial Forum,* 260 Madison Ave., N. Y. C., $3.00, 125 pp., 1956.—A presentation of papers and discussion on chemistry and production of metallic zirconium, fabrication, properties, corrosion behavior, alloys, supply of raw and refined materials, commercial products available, future AEC and industrial requirements, based on the proceedings of a two-day Forum meeting.

Germanium in Fly Ash and its Spectrochemical Determination, by J. S. Machin, and Juanita Witters, Circular 216, *State Geological Survey Div.,* University of Illinois, Urbana, Ill., free, 1956.—Report on the germanium content of fly ash in the Chicago area by spectrochemical means, with a detailed description of the method employed.

The Development of Markets for New Materials, by E. Raymond Corey, *Division of Research, Harvard Business School,* Cambridge, Mass., 257 pp., $4.00, 1956.—This volume presents the results of a study of how markets are built for new end-products. The study is based upon a number of actual case histories of marketing procedures in the aluminum, fibrous glass, and plastics industries. It is designed to describe details of market development and to abstract and analyze the common problems encountered.

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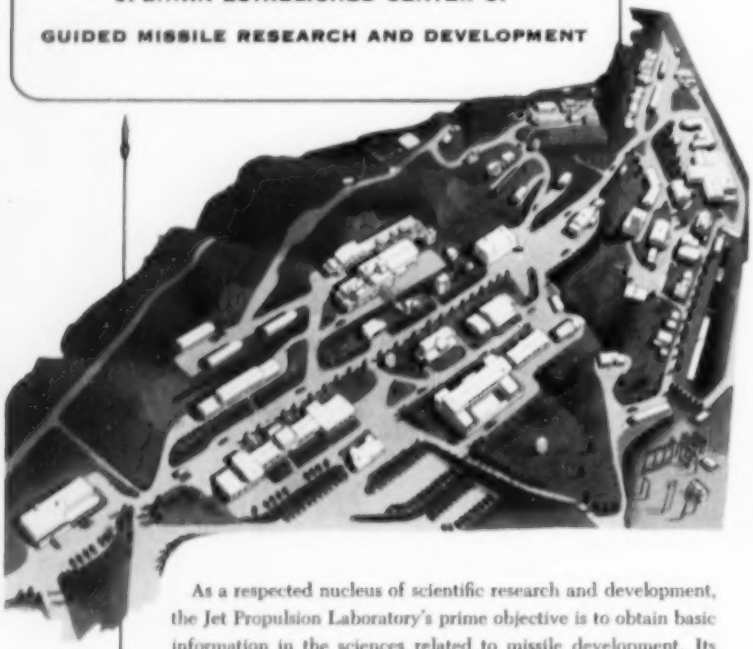

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Personnel

(Continued from page 1599)

ore analysis and extractive metallurgical tests. Will accept recent graduate. Salary, $4800 to $5400 a year. Company will pay placement fees. Location, Denver. W4208.

Sales Engineers, graduate metallurgists or chemical engineering degrees, to contact, on assignment, established and new accounts to determine equipment requirements in the mineral processing industry. Previous sales experience not essential. Travel, 25 pct. Base salary, $6000 a year plus commission. Company will pay fee. Headquarters, New York and also Denver. W4207.

Metallurgist, B.S., with three years metals experience or advanced degree required, to work in research and development of alloyed metal powders and in some of the scarce metals. Salary, $6000 or higher. Location, Massachusetts. W4188.

Metallurgist, with M.S. degree and at least five years experience in applied research in nonferrous materials. Salary, $8000 to $10,000 a year. Location, eastern Pennsylvania. W4127

Senior Metallurgist, B.S. degree, with five to nine years nonferrous experience on electronic tube materials. Salary, $9000 to $9600 a year. Location, Long Island, N. Y. W4120.

Sales Engineer, 30 to 40, with metallurgical and alloy welding experience, for sales and process engineering including clad metals. Salary, $8000 a year. Location, Newark, N. J., area. W4041.

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The ELECTROMET story is one of steady growth and progress for the benefit of the metal industries. When you buy from ELECTROMET, you get the best in alloys and service plus the advantages of long manufacturing experience and extensive research.

Here are some of the advantages you get from ELECTROMET'S *integrated programs.*

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Nine sales and service offices are strategically located in the major steel producing centers as shown on the map above. If you have a problem on metals or alloys, let one of our experienced metallurgists or sales engineers help you. He will be glad to assist you with any problems on the production of quality steels, irons, and non-ferrous metals. Simply telephone or write the ELECTROMET office nearest you.

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Since 1906 ELECTROMET has carried on a three-way program of research, development, and technical service. More than 300 skilled research scientists, engineers, and technicians work in ELECTROMET's Metals Research Laboratories and Development Laboratories at Niagara Falls (shown here). This program provides you with new ferro-alloys and metals, better ways of using them, and new and improved alloy steels and irons. Innovations are fully developed in our laboratories before they are offered commercially.

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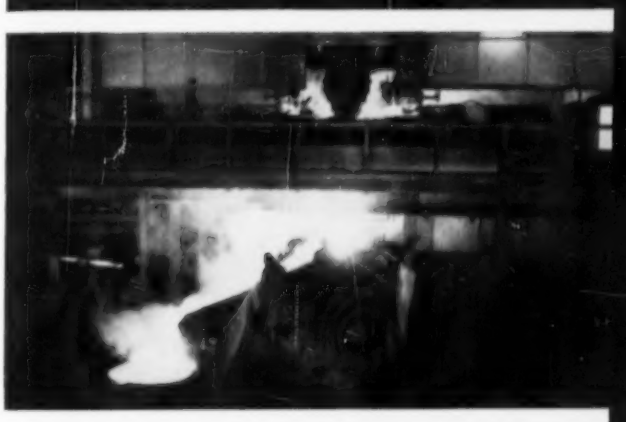

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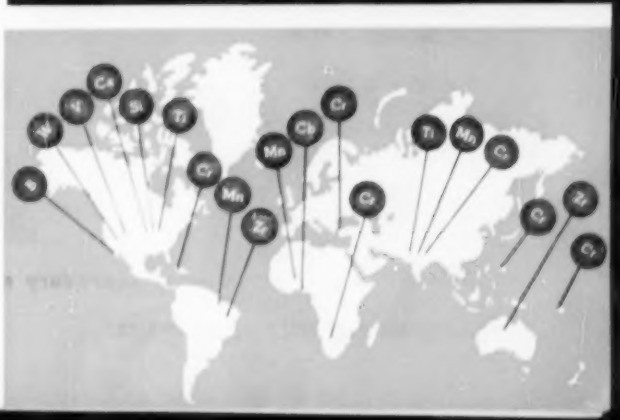
The availability of ores, and other raw materials is assured by ELECTROMET's diverse facilities, including mines and ore milling plants owned by UNION CARBIDE. Helping to assure adequate ore supplies are the ore buying facilities of Union Carbide Ore Company, a Division of Union Carbide and Carbon Corporation. Ores come from the far corners of the earth to ELECTROMET's plants. On this simplified map of the world, symbols for the chemical elements indicate a few of the major sources of alloy ores.



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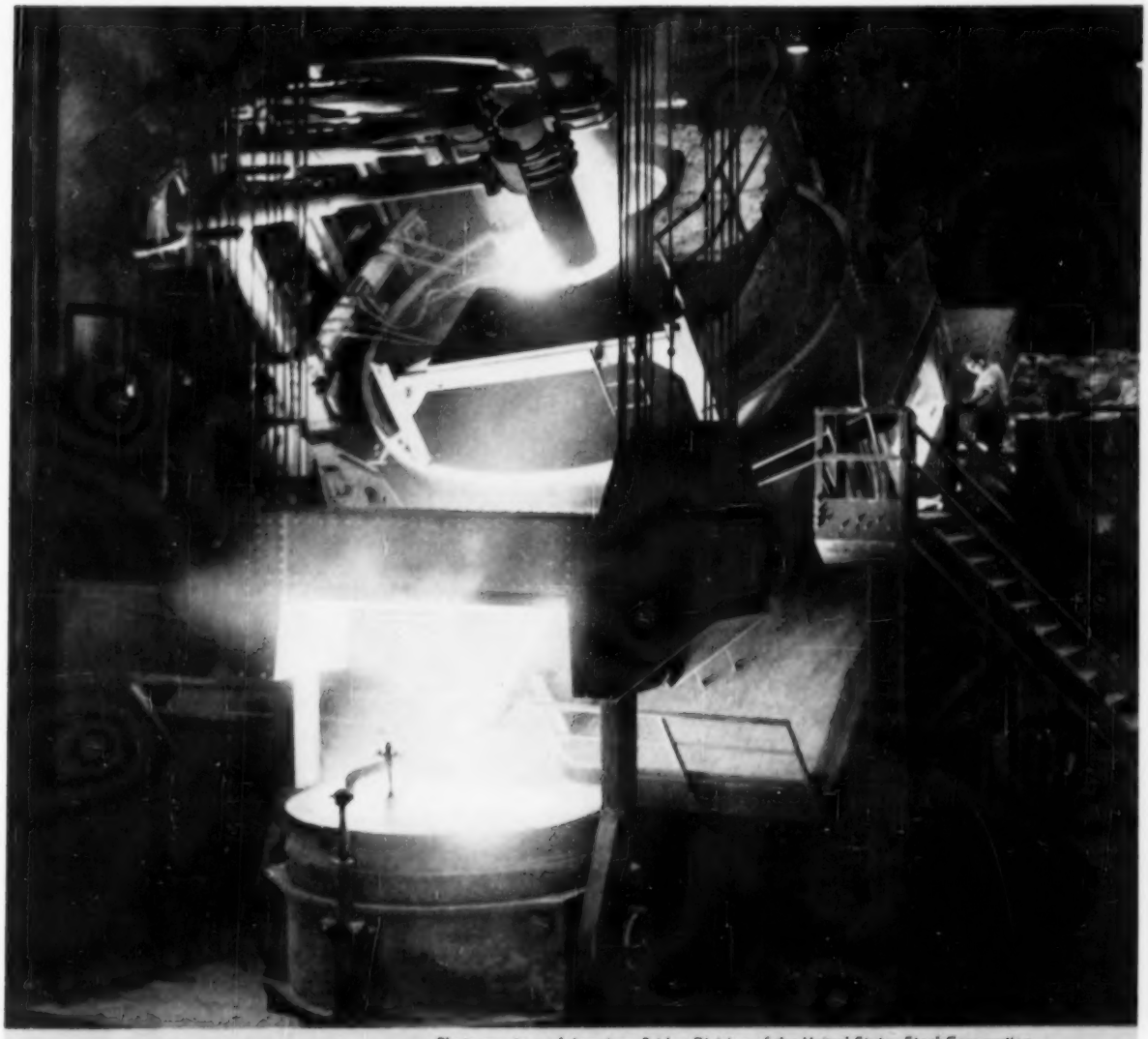

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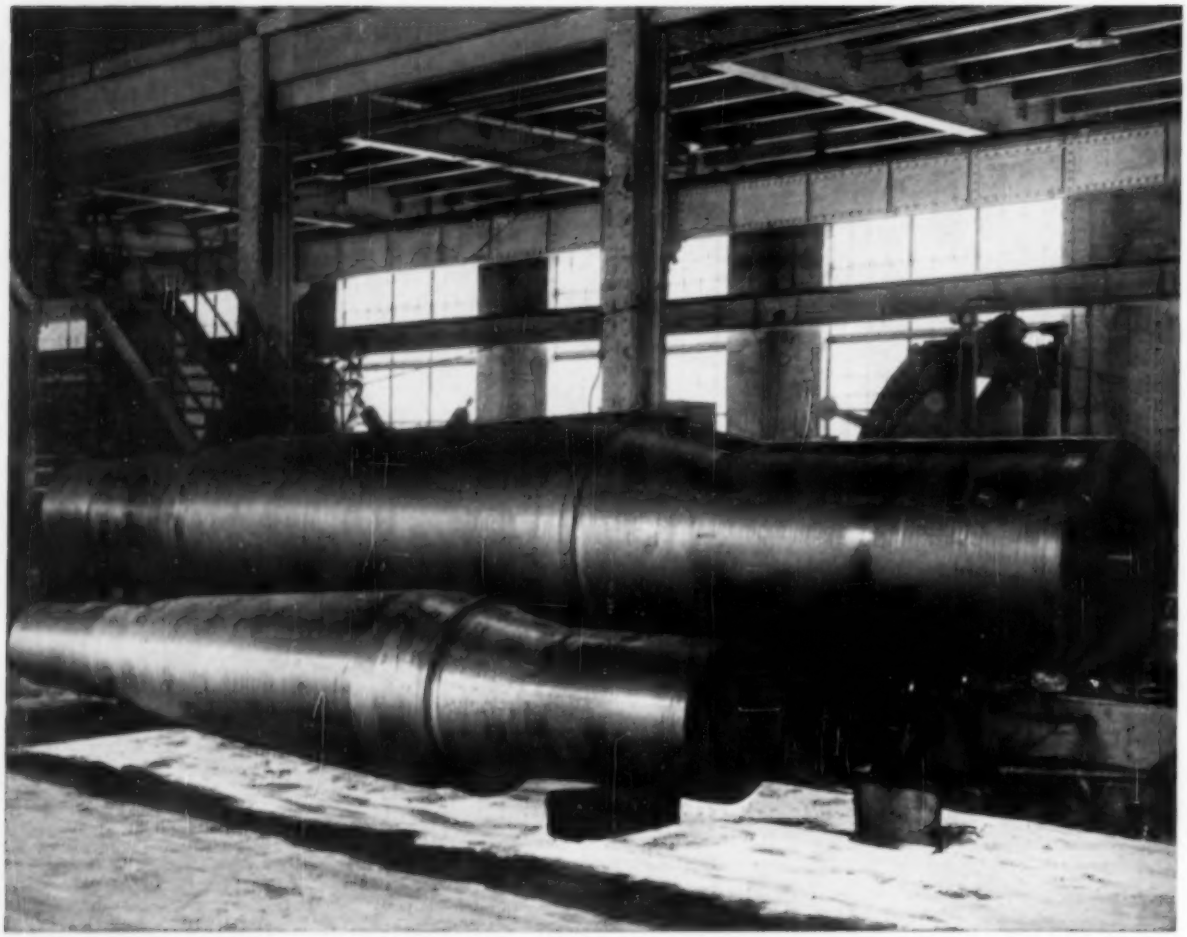

*Forged from 3½% Nickel Steel — These gyratory crusher shafts weigh 102,000 and 34,000 lbs. and are 25 and 17 feet long respectively. They were produced by Bethlehem Steel Company, Steelton, Pa.

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Electric Furnace Steel Production Ahead in 1956

Gain in output of electric furnace steel in the face of lower open-hearth and bessemer output is a feature of U. S. production during the first three quarters of 1956. This is due in small part to relatively higher electric output during the steel strike, and electric furnace steel is running 10 pct above 1955. Alloy steel continues to push output upward, although more than half of current electric furnace production is carbon steel.

The Suez Canal Situation

Recent blocking of the Suez Canal has been the cause of much concern among European industrial and financial circles. Some three-fourths of Europe's oil is derived from Middle-Eastern sources, and supplies can not be maintained at present levels by shipment around Africa. Europe must, therefore, draw upon oil sources in the Americas. Coal substitution is limited with mines already struggling to expand output. Thus, Belgium has ordered an extra one million tons of U. S. coal, and emergency orders are expected from other countries. The overall result for Europe: a growing dollar shortage, rising shipping and raw material costs, and strong inflationary pressure.

. . . and the British Steel Industry

The effect on steel production is nonetheless direct. More than one-third of British steel—over seven million tons—is produced in oil fired furnaces, and the steel industry is, in fact, the largest user of fuel oil except for refineries themselves. The possibility of substituting other fuels is limited.

. . . and the European Nonferrous Metal Industries

The Suez Canal is also of great importance in the transport of Malayan and Indonesian tin, Indian manganese ore, Australian lead and zinc, and other ores and metals. Tonnages which passed through Suez, westward bound, during 1955 are the following, in thousands of long tons:

Iron ore	2,044	Lead and lead ore	161
Manganese ore	1,687	Copper and copper ore	124
Zinc and zinc ore	326	Tin and tin ore	104
Titanium ore	286	Aluminum and bauxite	83
Chrome ore	252	Other ores and metals	233

. . . And Manganese Ore Shipments to the U. S.

Of the above shipments, U. S. interest centers chiefly on manganese ore, for some 833,000 tons passed through Suez enroute to our shores in 1955.

. . . And the Steel Market in the U. S.

The Suez Canal situation is adding to problems of the current tight market in heavy steel plate. The program to construct 50 supertankers, now being contemplated by the U. S. Government, would suddenly create a need for some 750,000 tons of heavy plate from an industry already operating at capacity.

. . . Further Repercussions May Be Expected

QUESTION:

Why is CORHART 104 different from other basic refractories?

ANSWER:

Corhart 104 is different from other basic refractories because of its method of manufacture. It is made by electrically melting conventional raw materials at 4450° F., and then pouring this refractory liquid into pre-formed molds where it solidifies, forming a homogeneous, interlocking crystalline refractory structure.

QUESTION:

What Advantages Are Available With CORHART 104?

ANSWER:

Corhart 104 offers the advantages of non-connecting porosity, interlocking structure and greater mechanical strength at operating temperatures. Its high density makes it more impermeable to gases and slags. Its absence of connecting porosity gives it a greater degree of corrosion resistance.

QUESTION:

When may we discuss possible use of CORHART 104 in your operation?

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The purification of silicon by Bell Laboratories metallurgists has been richly rewarding. Their original research in this field revealed the chemical factors that control semiconductors; it was a major advance leading to Bell Laboratories' invention and development of transistors and the Bell Solar Battery. Now they have devised a simple but highly effective way to remove boron—one of the most difficult impurities to extract from silicon.

During refining, a stream of hydrogen and water vapor is kept flowing past the silicon. As the water vapor passes over the liquid silicon, it seizes boron atoms, forming boron oxide. The oxide is then pulled away to condense on the wall of the refining tube which is cooled by a water stream. Result of refining: boron and other harmful impurities are reduced to less than one part in 10,000,000,000.

The new silicon is being used to develop still better transistors and rectifiers for telephony. It is another example of how Bell Laboratories metallurgists help open the way to improved telephony.

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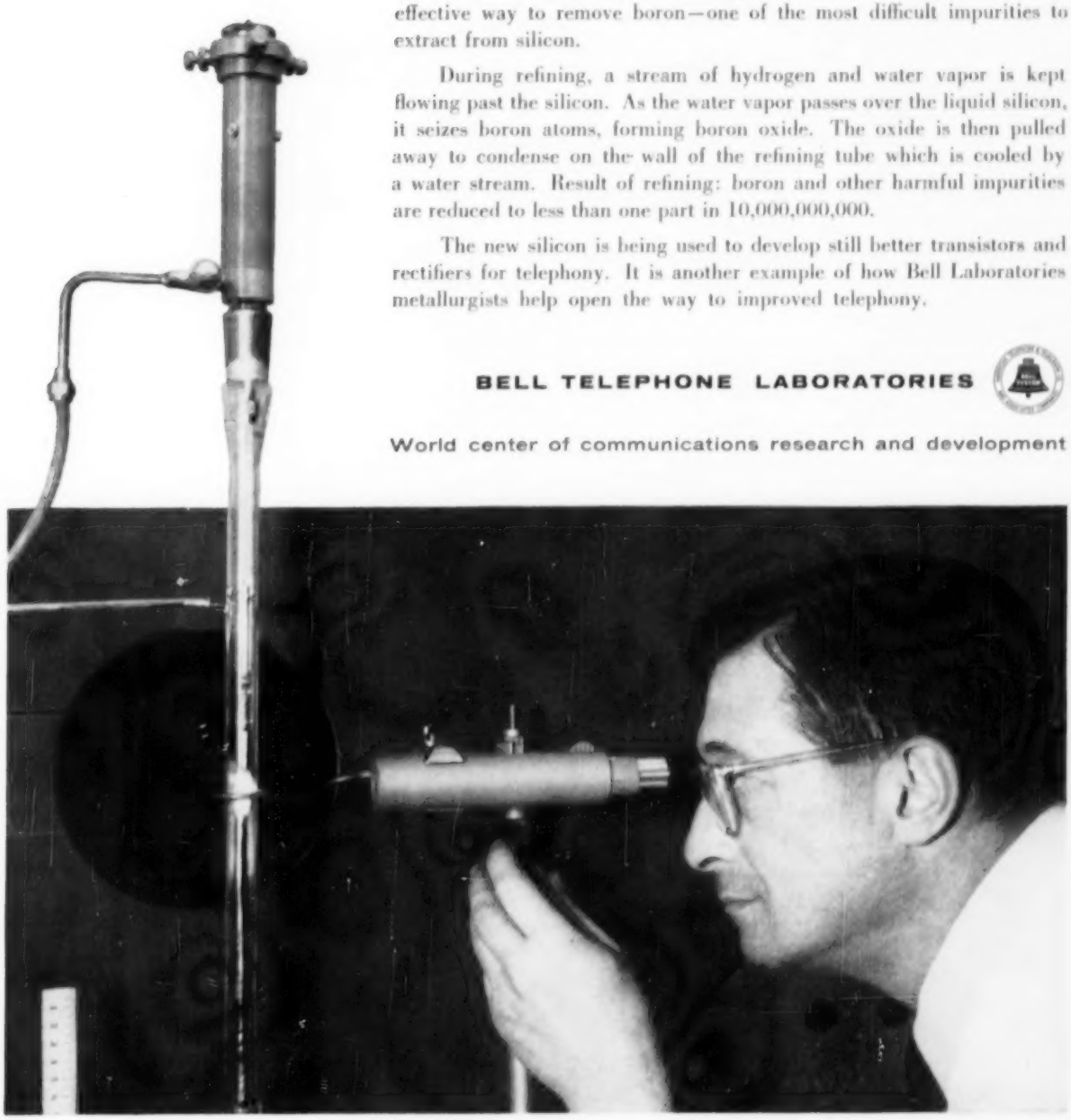
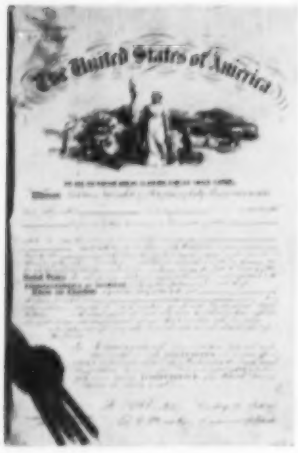
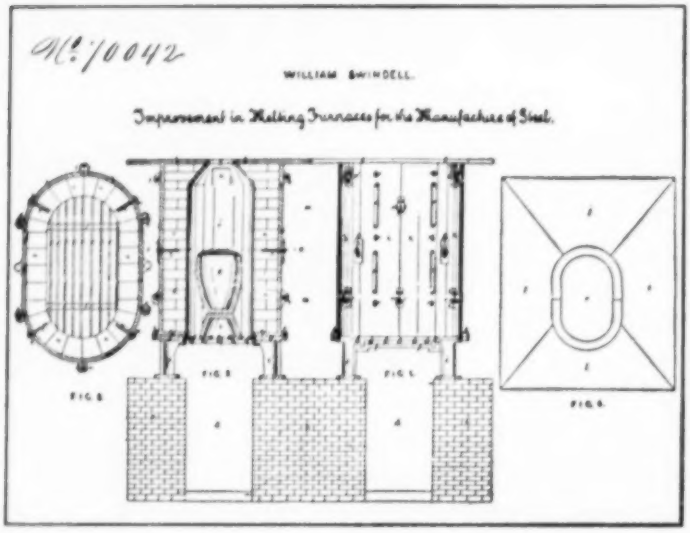


Metallurgist Henry C. Theuerer, M.A. in Chemistry, Columbia, watches a molten zone in a silicon rod under purification. Mr. Theuerer's most recent achievement was development of water-vapor treatment for removal of boron.





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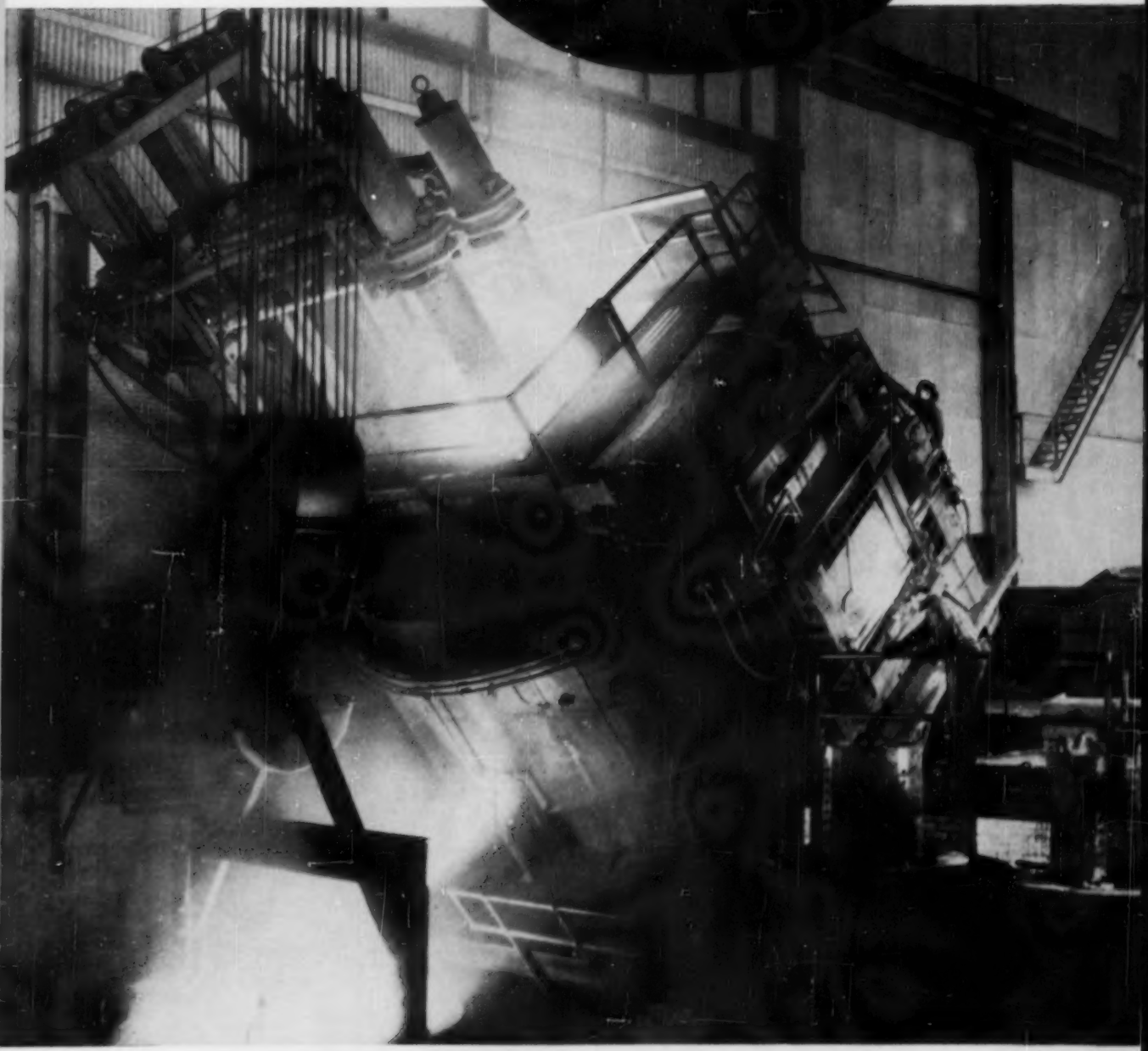
An early patent (No. 70,042 U. S. Patent Office) granted to Mr. William Swindell for an improved crucible furnace, for the melting of steel.



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EFSC Attendance

		1943	414		
1944	569	1948	534	1952	823
1945	500	1949	585	1953	749
1946	546	1950	620	1954	882
1947	569	1951	752	1955	949
		1956	?		

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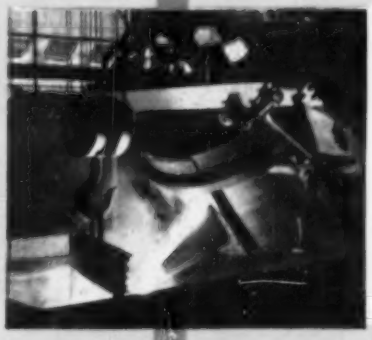

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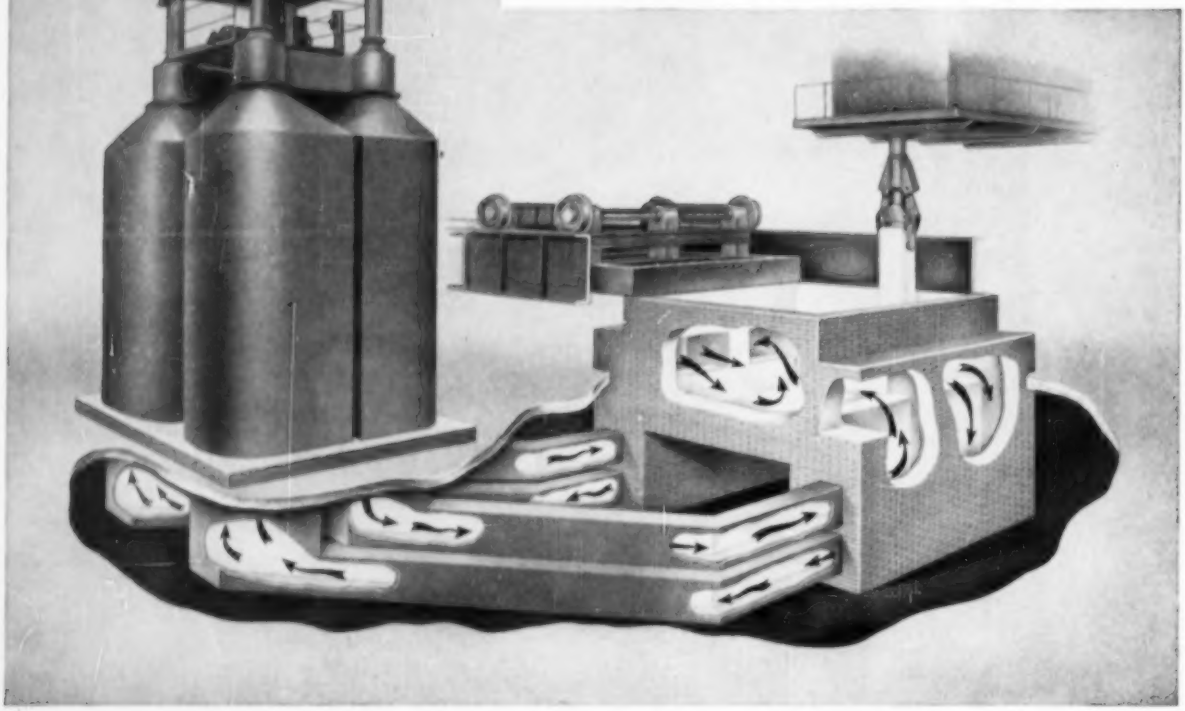

The schematic shows the flow of combustion air and flue gases through the regenerators and soaking pit. The Morgan-Isley system employs vertical regenerators. It eliminates regenerator capacity under the crane runway thus freeing this valuable area for heating steel.

CCC-49

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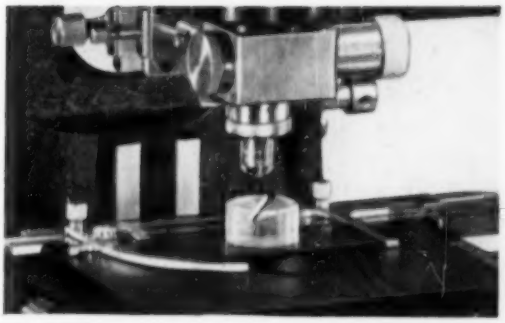

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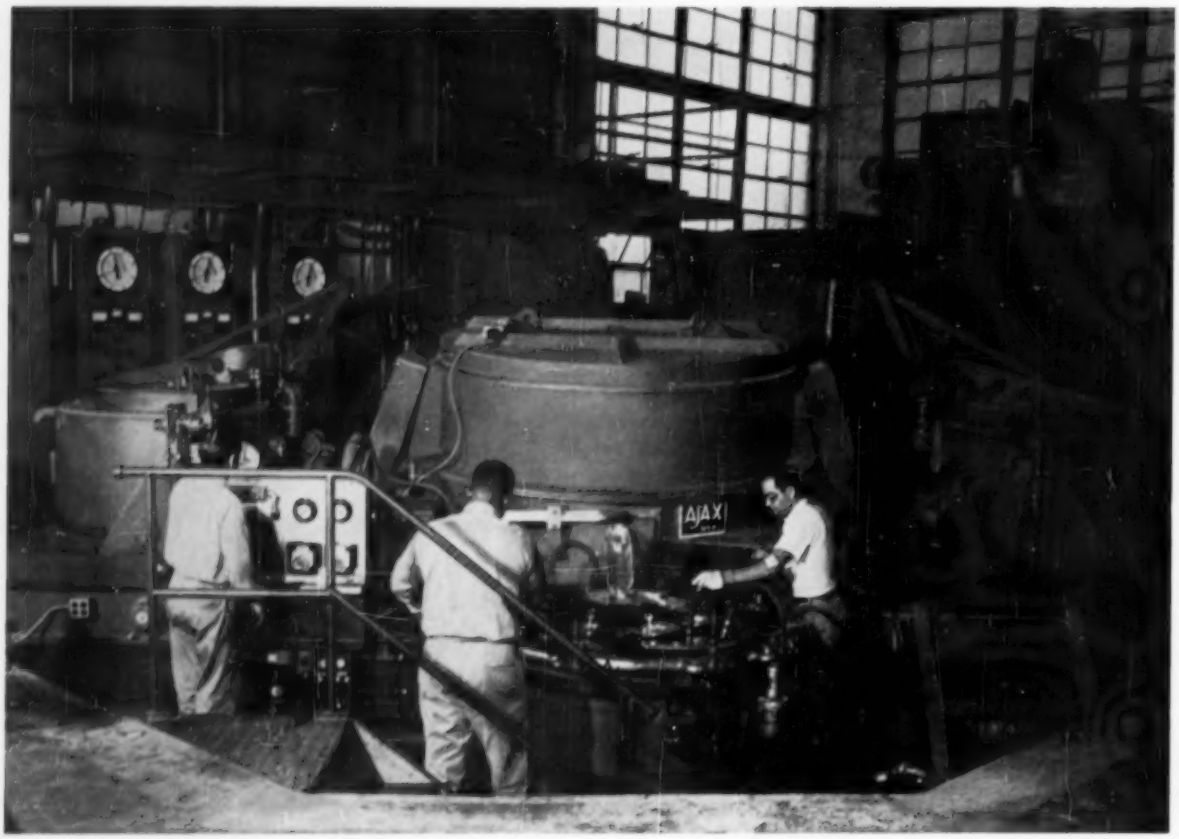

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14th Electric Furnace Steel Conference

REGISTRATION

Wednesday, December 5—9:00 am to 9:00 pm—Second Floor Foyer

Thursday and Friday, December 6 and 7—8:30 am to 5:00 pm—Second Floor Foyer

WEDNESDAY, DECEMBER 5

Plant Trips:

Republic Steel Corp.	American Steel Foundries
South Chicago Works	Indiana Harbor Works
Chicago, Ill.	East Chicago, Ind.

Chartered buses will leave from the Clark St. entrance of the Morrison Hotel at 11:00 am. Lunch will be provided by the host companies at Vogel's Restaurant, near the plants to be visited. There is a choice of visiting either the South Chicago Works of Republic Steel Corp., or the Indiana Harbor Works of American Steel Foundries. Buses will return to the Morrison Hotel by 4:00 pm. It is necessary for noncitizens of the United States or Canada to obtain a release from the company they plan to visit. They should make a request in writing to the company of their choice.

WEDNESDAY, DECEMBER 5

6:30 pm—Embassy Room

Electric Furnace Steel Committees Annual Dinner and Business Meeting
(All Chairmen of technical sessions are invited to attend)

6:30 pm—Walnut Room

Physical Chemistry of Steelmaking Committee Dinner and Business Meeting

THURSDAY, DECEMBER 6

9:30 to 9:45 am—Ballroom

GENERAL SESSION

Welcoming Remarks:
By D. L. Clark, Chairman, Committee for the Fourteenth Annual Conference

ANNUAL DINNER
THURSDAY, DECEMBER 6

6:30 pm—Constitution Room, Reception and Cocktail Party for dinner guests

7:00 pm—Ballroom, Dinner

Toastmaster: E. C. Logelin, Jr., Vice President, U. S. Steel Corp., Chicago, Ill.

Speaker: E. R. Johnson, Vice President in Charge of Operations, Republic Steel Corp., Cleveland, Ohio

Subject: *Men, Money, and Machines*

Response:
By C. E. Sims, Chairman, Electric Furnace Steel Executive Committee—Announcements and Reports

9:45 am to 12:30 pm—Ballroom

BROAD VIEW OF ELECTRIC FURNACE STEELMAKING

Honorary Chairman—H. B. Schulz, Consultant

Chairmen:
H. F. Walther, Melting Superintendent, Steel and Tube Div., The Timken Roller Bearing Corp., Canton, Ohio.
E. H. Weak, Consultant, Highland, Ind.

1. **Appraisal of European Electric Furace Melting**
   Paper by Robert Boutigny, Director of Engineering, Stein et Roubaix, Paris, France
2. **Fifty Years of Progress in Electric Arc Furnaces**
   Preprinted paper by Samuel Arnold, 3rd, Consulting Engineer, Pittsburgh, Pa.
3. **Trends of Electric Furnace Growth as They Pertain to Arc Furnace Transformers**
   Paper by Robert Bry, Manager of Sales, Transformer Apparatus Section, General Electric Co., Pittsfield, Mass.
4. **Cyclical Rises and Declines in the Price of Steel Scrap**
   Paper by Chapin Hoskins, Chairman, Institute of Trend Research, Hopkinton, N. H.

2:00 to 5:00 pm—Ballroom

SOLIDIFICATION OF ELECTRIC FURNACE STEELS

(Organized by Physical Chemistry of Steelmaking Committee)

Chairmen:
C. W. Sherman, Director of Research, Latrobe Steel Co., Latrobe, Pa.
Gerhard Derge, Jones and Laughlin Professor of Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

1. **Solidification of Various Metals in Ingot and Sand Molds**
   Preprinted paper by W. S. Pellini, Superintendent of Metallurgy Division, Naval Research Laboratory, Washington, D. C.
2. **Macrosegregation, Microsegregation, and Inclusion Types in Chrome-Nickel and Chrome Steels**
   Paper by J. C. Fulton, Research Advisor, and R. H. Henke, Manager, Quality Control, Allegheny Ludlum Steel Corp., Brackenridge, Pa.
3. **Solidification of Stainless Steel Ingots**
   Paper by B. R. Queneau, Chief Metallurgist, Duquesne Works, United States Steel Corp., Duquesne, Pa., and D. J. Carney, Superintendent No. 2 Electric Furnace Shop, South Works, United States Steel Corp., South Chicago, Ill.
4. **Some Observations on Deoxidation and Hot Ductility of Type 310 Stainless Steel**
   Paper by R. A. Perkins, Research Metallurgist, Metals Research Laboratories, and W. O. Binder, Assistant Manager, Product and Process Development Department, Electro Metallurgical Co., a Division of Union Carbide and Carbon Corp., Niagara Falls, N. Y.

5. **Shrinkage and Density of Liquid Killed Steel in Hot Topped Ingots**
   Preprinted paper by L. H. Nelson, Director, Conservation and Yield Control, Crucible Steel Co. of America, Pittsburgh, Pa.
6. **Relation of Ingot Structure to Transverse Ductility of Heat Treated High Strength Steel**
   Paper by J. V. Russell, Metallurgical Laboratory Director, and C. R. Weymuller, Metallurgist, Chicago District, Republic Steel Corp., Chicago, Ill.
7. **Gas Problems in the Solidification of Steel**
   Paper by T. B. King, Assistant Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

FRIDAY, DECEMBER 7

9:30 am to 12:30 pm—Ballroom

DEVELOPMENTS FOR CONTROL OF QUALITY AND INTERPRETATION OF RESULTS

Chairmen:
L. F. Weitzenkorn, Works Metallurgist, Baltimore Works, Armco Steel Corp., Baltimore, Md.
W. J. Mathews, Jr., Superintendent of Melting, Columbia Tool Steel Co., Chicago Heights, Ill.

1. **Rapid Hydrogen Analysis and Some Applications**
   Paper by W. A. Peifer, Research Engineer, Allegheny Ludlum Steel Corp., Brackenridge, Pa.
   Discussion by D. W. Murphy, Research Engineer, Bethlehem Steel Co., Bethlehem, Pa.
2. **Molded Exothermic Lined Hot Tops**
   Preprinted paper by H. D. Shephard, Metallurgical Engineer, Foundry Services, Inc., Columbus, Ohio
   Discussion by W. Heck, Melting Superintendent, Braeburn Alloy Steel Corp., Braeburn, Pa.
   Discussion by H. O. Beaver, Jr., Plant Metallurgist—Melting, The Carpenter Steel Co., Reading, Pa.
3. **Use of Statistical Machines and Methods for Quality Control**
   Paper by W. R. Weaver, Director of Steel Conservation and Quality Control, Republic Steel Corp., Cleveland, Ohio.
   Paper by J. J. Oravec, Chief Process Metallurgist, Duquesne Works, U. S. Steel Corp., Duquesne, Pa.
   Discussion by C. R. Taylor, Supervising Metallurgist, Armco Steel Corp., Cincinnati, Ohio.
   Discussion by D. C. Hilty, Research Metallurgist, Metals Research Laboratories, Electro Metallurgical Co., a Division of Union Carbide and Carbon Corp., Niagara Falls, N. Y.

9:30 am to 12:30 pm—Constitution Room

NEW APPROACHES TO HOT TEARING PROBLEMS AND LADLE REFRACTORIES

Chairmen:
P. R. Gouwens, Chief Metallurgist, Fahralloy Co., Harvey, Ill.
C. B. Williams, Works Manager, Massillon Steel Casting Co., Massillon, Ohio

1. **Relationship of Freezing Characteristics to Hot Tearing and Deoxidation**
   Preprinted paper by C. F. Christopher, Director of Research, Continental Foundry and Machine Division, Blaw-Knox Co., East Chicago, Ind.
   Discussion.
2. **Evaluation of Ladle Refractories**
   a) **Zirconite Ladle Linings**
   Preprinted paper by W. D. Emmett, General Superintendent, Los Angeles Steel Castings Co., Los Angeles, Calif., and V. E. Zang, Vice President and Director of Research and Development, Unitcast Corp., Toledo, Ohio.
   Paper by W. A. Koppi, Melting Superintendent, Lebanon Steel Foundry, Lebanon, Pa.
   b) **High Alumina Linings**
   Paper by V. J. Howard, Melting Foreman, Oklahoma Steel Castings Co., Tulsa, Okla.
   c) **Ganister Vs. High Alumina**
   Paper by Charles Faist, Metallurgist, Burnside Steel Foundry, Chicago, Ill.
   Discussion.

2:00 to 5:00 pm—Ballroom

FUME CONTROL AND SCRAP SOURCES

Chairmen:
W. M. Patterson, Electric Melting Consultant, Allegheny Ludlum Steel Corp., Brackenridge, Pa.
C. W. Yutmeyer, Division Superintendent of Steel Production, Crucible Steel Co. of America, Pittsburgh, Pa.

1. **Smoke and Fume Control**
   Paper by H. W. Peterson, Sales Engineer, Freyn Department, Engineering Construction, Koppers Co., Pittsburgh, Pa.
   Preprinted paper by C. Finkl, Plant Engineer, A. Finkl and Sons Co., Chicago, Ill.
   Discussion by J. R. Atkinson, Dominion Foundries and Steel Co. Ltd., Hamilton, Ont., Canada
2. **Sources of Iron Other Than Scrap**
   a) **Overall Picture of Sponge Iron and H-Iron**
   Paper by P. E. Cavanagh, Director, Department of Metallurgy, Ontario Research Foundation, Toronto, Ont., Canada.
   b) **Practical Aspects of Using Sponge Iron**
   Paper by John Stalhed, General Manager, Sponge Iron Div., Stora Kopparberg Corp., Soderfers, Sweden.
   c) **Molten Pig Iron**
   Paper by W. A. Hoff, Melt Shop Metallurgist, Republic Steel Corp., Chicago, Ill.
   d) **Desiliconized Pig Iron**
   Paper by S. Case, Technical Advisor, Battelle Memorial Institute, Columbus, Ohio.
   Discussion by H. W. McQuaid, Consulting Metallurgical Engineer, Cleveland, Ohio.
3. **Efficient Preheater for Electric Furnace Charges**
   Paper by R. J. Leary, Supervising Extractive Metallurgist, U. S. Bureau of Mines, Pittsburgh, Pa., and W. O. Philbrook, Professor of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

2:00 to 5:00 pm—Constitution Room

OPERATIONS: BULL SESSION

Chairmen:
N. H. Keyser, Assistant Chief, Process Metallurgy, Battelle Memorial Institute, Columbus, Ohio
H. C. Templeton, Chief Metallurgist, L. F. M. Co., Atchison, Kansas

1. **Bull Session—Why Oxygen?**

   Why We Use Oxygen in Our Acid Electric Furnace

   Preprinted paper by E. J. Etowski, Metallurgist, and Ray Perry, Chief Metallurgist, Farrell-Cheek Steel Co., Sandusky, Ohio
   Discussion by J. S. Absalom, Research Metallurgist, American Steel Foundries, East Chicago, Ind.
   Discussion by A. F. Gross, Research Metallurgist, Ohio Steel Foundries, Springfield, Ohio
   Discussion by V. T. Popp, Metallurgist, Cooper Alloy Corp., Hillside, N. J.
   Discussion by Leroy Fink, Metallurgist, Electric Steel Foundry Co., Portland, Ore.

DRIFT

Affiliate Membership in EJC Evaluated

THIS is in answer to many requests for information concerning the role of Engineers Joint Council in the engineering profession, particularly the role of its Affiliate Member societies.

The profession is represented by societies formed of individual members having a common technical interest. To facilitate communication between members, local sections or chapters of national societies have been formed to operate in communities or geographical areas. In addition, there are many local or regional societies composed of members from the several branches of engineering.

The technical phase of the profession has been developed to a high degree by each society, but the impact of the profession on the public by the individual, his local section, or national society requires a coordinated effort by all the segments of the profession. Engineers Joint Council provides the medium for this effort.

Associate and Affiliate Societies

Associate Member societies are national in the activity and technical interest of their members, differing only in size from the larger Constituent societies.

The Affiliate Member societies are composed of either of two types of organizations, or even a combination of both. One is the local or independent regional society, organized and operating for the benefit of the engineers in an area. The other, of greater importance here, is the federation of engineering societies, or local sections or chapters of such societies.

Since all individuals trained in the engineering profession are engineers first and specialists second, there has developed the need for a common medium of expression. The federation of local sections and/or regional societies provides a forum for specialists with the one common interest, the profession of engineering, to become associated in affairs of public interest.

Engineers, as professional persons, are obligated to devote part of their time and effort to matters affecting public interest. In order to help the engineer obtain proper public recognition and professional status, the public must know of him both as an individual and as a member of a group. The federation provides the medium through which the public may call on the individual or the group for the service and help that it needs.

At national level, EJC provides the connecting link between the national and the local societies or federations, which find the problems in their communities are similar to those in other communities and thus look to EJC to aid in finding an adequate solution.

EJC has a long-established and well-defined interest in policy contained in legislation affecting the engineering aspects of the development of the country, but in no instance has it taken a positive stand on a specific item of legislation. Local federations, state or regional, if formed and operated along the same pattern as EJC, would probably be permitted the same latitude of action within their fields of interest.

A local federation enhances its effectiveness by becoming an Affiliate Member Society of EJC. A national policy has no value unless it has the support of the local members; the individual engineer cannot know accurately what the national policy is and how it may affect the community in which he lives except through group action.

The question has often been raised concerning the advantages of dual representation in EJC. One comes through regular membership in a national society with the society board representatives speaking for their members at the EJC Board. The other comes through an observer from a federation, which has a voice at all meetings of the EJC board and a vote at the annual meeting of the board. Each serves a specific purpose. The national society board member reflects the considered opinion of the majority of the members at the national level, while the observer from the federation brings to the EJC board the specific policy problems of the area which he represents. The opinions of each are essential to the establishment of satisfactory basic policy that will be of value and benefit to the profession and the public which we serve.

Science is continuing to provide engineering with ever-expanding vistas. The utilization of new metals, the applications of nuclear phenomena, the harnessing of the vast store of solar energy, electronic and mechanical developments in automation, increasingly invest the engineering profession with social as well as technological responsibilities. The activities of this influential and representative federation of engineering groups striving to bring to bear the weight of the entire profession on these problems should stir the imagination and enlist the support of every engineer.

E. Paul Lange

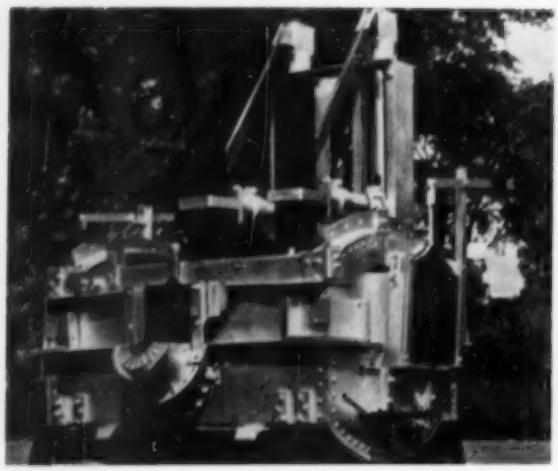
(Ed. Note: Excerpted from an address presented by the author, EJC Secretary, at the Pacific Southwest Council of Local Sections of ASCE, April 19, 1956. Background information on "The Role of EJC in the Profession" appeared in JOURNAL OF METALS *Drift, April 1956.)*

Utica
Metals
Division
U TI CA
UTICA DROP FORGE & TOOL
Division of Kelsey-Hayes Wheel Co.
UTICA 4, NEW YORK
An Open Letter
ON VACUUM MELTING
To the man responsible for product development and improvement:
The problems of vacuum melting in production quantities have been solved. There are considerable data available on the properties of various alloys.
But the work has just begun.
There remain many unexplored promising uses for vacuum melted alloys -- and these uses must be explored by product manufacturers. To them we offer our knowledge, our facilities and, within our means, our purse.
Bring us your problems, your ideas, your questions. If you're looking to the future you need a supplier who is too.
Sincerely,
F.N. Darmara
General Manager
Metals Division
P.S. Utica can offer you properties like these through Vacuum Melting:
• High temperature corrosion resistance
• Extreme cleanliness
• Precise chemical control
• Longer stress-rupture life
• Increased tensile strength
• Increased ductility
• Better fatigue resistance
• Greater yield strength
• Greater impact resistance
• Greater creep properties
U DI MET

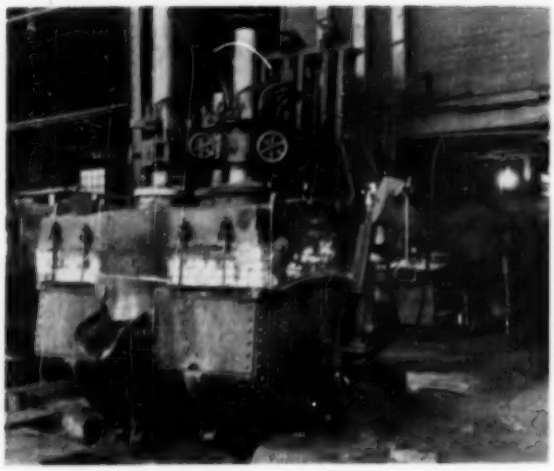
Dr. Paul Héroult, 1864-1914

The First Half-Century of Electric Furnace Steel Making

Based on an Article by S. B. Casey, Jr.



This furnace poured the first heat of electric furnace steel in America on April 5, 1906. It now stands enshrined on its original site at the Sanderson-Holcomb Works of Crucible Steel Co. of America at Syracuse, N. Y.



The Treadwell Engineering Co. made the first electric steel castings in America with the above furnace. Initial heat was poured on November 11, 1911.

IN 1880, an electric arc was struck over metal for the first time to experiment with controllable melting. The glare of this arc has reflected on the stacks of the steel industry and continued to light the path of steelmakers in their never ending quest for faster, more economical, and better ways of producing steel.

William Siemens is credited with first employing the electric arc to melt metal in a closed hearth and produce basic metallurgical reactions. By the turn of the century, an Italian, named Stassano, was experimenting with ore reduction by the electric arc. In 1899, Dr. Paul Heroult, in France, used the direct arc principle for producing ferro-chromium. His experiments quickly led him to develop a closed-top arc furnace for the production of steel, and his first commercial shipment was recorded in December, 1900.

American steelmakers, quick to sense the possibilities of this method of melting, invited Heroult to our shores, where, in 1905, he was responsible for installing the first arc furnace on the North American continent. This furnace, at Sault Ste. Marie, was built for ore reduction. But Charles Holcomb, founder of Holcomb Steel Co. of Syracuse, N. Y. contacted Heroult in 1905 and contracted for the first American direct-arc electric furnace for steelmaking. On April 5, 1906, the first heat was tapped from this 3-ton unit. The furnace was basic lined and powered by a single-phase, 500 kw generator, producing high amperage at low voltage.

It is interesting to note that, although the first few heats were made with cold charges, subsequent heats were duplexed. R. H. Bully, first superintendent of Holcomb Steel, persuaded the directors to purchase the unit to effect a more economical and efficient means of making toolsteel by duplexing—prime melting in a combustion fired furnace, and transfer of hot metal to the arc furnace for temperature adjusting, refining, and adding carbon and alloying elements. Today, duplexing is foreseen by some as *the* steelmaking process of the future.

The promise shown by America's first arc furnace for ingot production quickly led to the purchase of a similar unit by The Firth Sterling Steel Co., in 1909, and to the purchase of the first arc furnace for production of steel castings, by the Treadwell Engineering Co., in 1911. From its humble start in 1906, production of arc furnace steel has never ceased to increase its yearly percentage of total steel production in the U. S., although certain other methods have declined or almost disappeared.

By its ability to be used intermittently, the arc furnace gained favor and enhanced its reputation during depression days. When the attack on Pearl Harbor plunged us headlong into the long days of World War II, the arc furnace stood ready, flexible enough to be overburdened hearthwise 30 pct and powerwise 25 pct, pouring its endless flood of alloy for the guns, tanks, ships, and planes which ultimately brought victory.

During the post war boom, the now proven virtues of low initial cost, faster installation, better yield, improved availability, and lower operating cost, enabled industry—particularly the small, new, independent producers—to locate strategically and profitably to meet the demand of an America that had been starved for new homes, appliances, cars, and highways.

In the Korean *police action*, the arc furnace again proved itself by providing the latest alloys metallurgists could develop to meet the demands that the jet age and the innovations of guided missiles required.

In today's peacetime prosperity, the arc furnace is continuing to provide the economic flexibility required to meet an ever increasing demand for better steel in the face of mounting costs, scrap shortages, and pressure toward decentralized location of industry.

Evolution of Furnace Design

From the original hand-charged, 3-ton capacity furnace of 1906, to the giant, top-charged, cylindrical shell of 1956, with its semi-spheroidal hearth rated at 200-ton capacity, the arc furnace has seen many interesting design changes.

Before it was a year old, the low-roofed, oblong-shelled prototype saw its first basic change when the roof was raised almost a foot from the hearth surface. A later prototype of furnace shell was cylin-

S. B. CASEY, JR. is Sales Engineer with the Swindell-Dressler Corp., Pittsburgh, Pa.

drical and mainly of the flat bottomed, single-phase type.

Melters devised chutes and peels to speed charging through furnace doors, and ability of the arc furnace to be tilted helped to distribute the scrap. In some instances, electric furnaces were built alongside existing open hearths, and where door space permitted, they were charged by the open hearth charger. It appears possible that the traffic burden thus imposed may have served as a factor in the development of top charging.

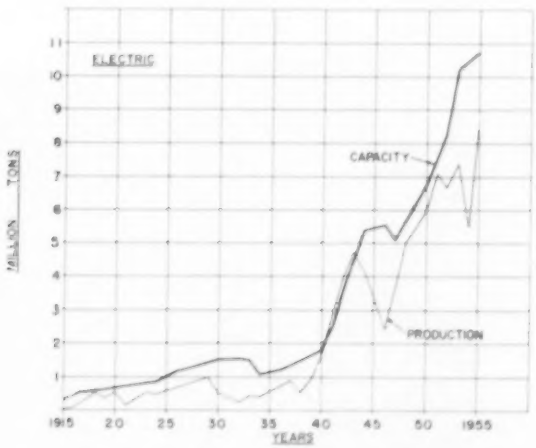
As early as 1910, U.S. Steel installed a three-phase electric furnace. But, while development of cylindrical tilting shells and three-phase equipment began the design trend toward larger furnace sizes, the greatest single impetus was afforded by top charging.

About 1920, the Snyder *coffee-pot lid furnace* appeared. It was designed to cant the electrodes and roof upwards and back, thus exposing almost half of its top to charging pans. Damage to roof and electrodes minimized the powerful effect of decreased charging time, yet this did mark a step forward.

In 1924, Swindell engineers devised the first top-charged electric furnace in which the horizontal position of the roof was maintained while it was raised and moved aside. This furnace consisted of a stationary electrode system and a two-shell turntable, one shell being tapped and charged while the other shell was in melting position beneath the electrodes. At least two of these units are still in operation.

Considerable apprehension was voiced by industry concerning the ability of the hearth, refractories, and furnace unit to withstand the impact of dropping a charge of cold metal into the open top of an arc furnace. Experience quickly showed that the hearth actually compacted if reasonably protected by *cushion* scrap placed in the bottom.

With the impetus thus afforded by a faster charging method, the number of furnace installations increased greatly. Various engineering approaches to top charging evolved the gantry type furnace, wherein the roof was lifted and swung clear of the shell by a gantry method. This method was employed by Heroult for many years and led to European versions wherein the roof was lifted while the shell was transferred for charging.



The above chart gives ample reason for optimism about the second half century of electric furnace steel.

Door charged units converted to top charged units in 1935 indicated that capacity was increased 11 pct, number of yearly heats increased 12.5 pct, savings in scrap cost were 5 pct, and annual production increased 25 pct with a saving of 10 pct in operating costs. In terms of manpower, the top charged furnace produced 87 pct more steel per man hour than its door charged counterpart.

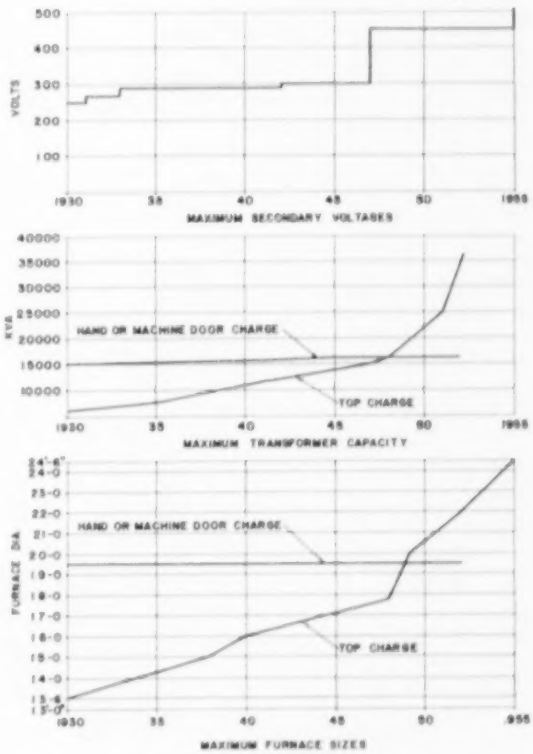
There was also a development in shell height. This 1937-1956 trend—based on 50-ton furnaces supplied to an eastern steelmaker—shows a 70 pct increase in shell height brought on by top charging.

Scrap under 90 lb per cu ft was once considered economically unusable, but the advantages of top charging allowed the arc furnace to take advantage of this less dense material. In today's accepted furnace design, the roof is lifted and swung aside hydraulically or mechanically, enabling 75-ton units to be charged in 5 to 10 min with scrap density as low as 30 lb per cu ft.

Development of Electrical Equipment

The first melters would have been better able to cope with their jobs if they had been born with three arms. Early regulators were handwheels or cranks. Motor driven winches to hoist electrodes soon appeared, and the job of raising and lowering electrodes was done by push buttons with electric lamps connected between the electrodes and ground to indicate voltage. Thus, input was shoddy, and abuse to electrodes and electrical equipment was severe.

The first three-phase furnace transformer promoted increases in furnace size and number during the early 20's. From 500 kw units and early units with single voltages of 90, 95, and 100 v, the first



Factors contributing to increased production of electric furnace steel are shown above. Note the importance played by the change-over to top charging.

no-load tap changer evolved in 1925 with a voltage range of 90 to 135 v.

During this time, oil circuit breakers, designed for transmission purposes, were used to switch power off and on, but the increasing repetitive duty brought on by tap-changing, furnace short circuits, and top charging, forced development of a true arc furnace circuit breaker, with changes in mechanical design, rupturing capacity, and interlocking.

By 1928, kva ratings increased to 7500 kva, and secondary voltages were on the order of 275 v. Delta Delta to Delta Star switching made the voltage range more flexible, and attempts were made in 1930 to use 300 v with a special bus arrangement for 500 v.

Strides in transformers and circuit breakers were being matched by developments in regulation. Push button control was replaced by the early Seede (contact making ammeter) type regulators with no consideration given to voltage. This, at least, took the 100 pct human element, represented by all manual operation, out of the equation.

Later, the AU type balanced beam regulator was developed; it is still seeing service. This regulator balanced current and voltage on a mechanical arm. It offset the ever-increasing electrode burn-off rate and the more severe melting conditions that were developing as furnaces grew bigger, transformer ratings increased, and scrap conditions grew worse.

A similar increase was developing in kva ratings for a given furnace size, and as these ratings increased, the impedance of the secondary path grew to such an extent that difficulty was encountered getting power into the furnace charge. To surmount this condition, secondary voltages were increased beyond prior bounds, and the furnace circuit was redesigned to lower its impedance. Resultant high voltages caused excessive arc lengths, and refractory costs sky-rocketed. A long period of trial and compromise between voltage and impedance resulted, but improvements in refractories and furnace proportions helped in finally solving the problem.

In 1940, the first rotary regulators were tested and installed. These regulators, based on the Ward-Leonard principle, responded instantaneously to conditions inside the furnace, and moved electrodes at the speeds necessary to combat these conditions. Since they consisted of motor generator units, they had few moving parts, thereby greatly reducing maintenance costs. Today, this type regulator is an accepted standard and affords electrode hoisting speeds up to 160 in. per min.

After World War II, the arc furnace air circuit breaker came into its own. Its design carried it into voltage ranges up to 34.5 kv, with rupturing capacities up to 1 million kva I.C. Being specifically designed for the highly repetitive duty demanded by today's practice, the air breaker has almost entirely satisfied the bulk of recent arc furnace breaker sales.

When furnaces of over 100-ton capacities were developed, there was little use in applying voltages under 300 v to achieve an imput of say 20,000 kva, since the impedance was such that, with increased current, input could fall below normal as the power factor dropped off. Thus, the furnaces were redesigned to lower impedance, voltages were raised, and although a study of changing frequency was considered, this trend never really got started.

Other Developments Speed Operation and Cut Downtime

As furnace diameters became larger, two doors were installed to permit ease of repair to the bottom and banks. During the 1930's, the shell also evolved from the side door type, tapping away from the vault (when deslagging was done through the spout), to a type where the furnace tilted forward for tapping, and deslagging was done at the slag door opposite the spout. A side door at 90° to the tilting axis provided the furnace with an opening for additions and hearth maintenance.

Drop-leaf, rope-tie charging buckets replaced older charging pans. In large shops, these were replaced by a trip latch mechanism, which eliminated the rope tying operation as well as the interminable delay of the bucket over the furnace while waiting for the rope to burn.

A 100-ton, elliptical shell furnace with six electrodes is shown being serviced by an open hearth charger. It was installed in 1927 at Timken Steel and Tube Div.

In the early 1950's Harold Phelps, of Rotary Electric, made a major contribution to the charging of electric furnaces with his adaptation of the old clam-shell design to scrap buckets. This eliminated rope expense in the amount of $75,000 per year in large shops, permitted faster more controllable charging, eliminated the closing stand and tying operation, and the bucket once closed could be used as a leveling device.

Faster electrode hoisting, tubular-bus, water-cooled electrode holders, oversized roof rings, replaceable panel type shells, water cooling, and a flush door operating mechanism, were all vital factors in improving production and reducing downtime to give the electric furnace the notable production rate and availability factor it currently enjoys.

Electrodes—of amorphous carbon, usually of square or semi-octagonal cross section—were first imported from Sweden. Early American counterparts were still made of amorphous carbon, but they had a circular cross section. Self-baking Soderberg electrodes were tried but never fully accepted on top charged units, partially because of their bulk.

In the early 1920's, a definite trend to the denser and more conductive graphite electrode became evident, since its greater current capacity per unit diameter enabled the electrode circle to be decreased. This gave better electric characteristics and a definite improvement in refactory life. These smaller graphite electrodes also decreased radiation and oxidation losses and did much toward lessening the inertia problem then evident in the fast reversal requirement of raising and lowering the electrodes.

Later improvements in electrodes were in terms of concentricity, tolerance of diameters, column strength, nipple joints, and tightening techniques.

The Second Half Century

The arc furnace has an impressive future. With its inherent advantages of flexibility to changes in production schedule and changes in the steel market, and its relative geographical independence, allowing plants to be placed near markets, it is hard to tell how fast electric furnace steel production will grow, but grow it will. The last six newcomers to the steelmaking industry use arc furnaces as their melting medium.

Fuel costs, the big factor favoring the open hearth today, can be expected to favor the arc furnace in the future. It is foreseen by experts that by 1975, open hearth fuel costs may increase 20 to 25 pct in terms of 1956 dollars, whereas, the constantly increasing efficiency of electric generating plants is expected to lower the cost of electric power.

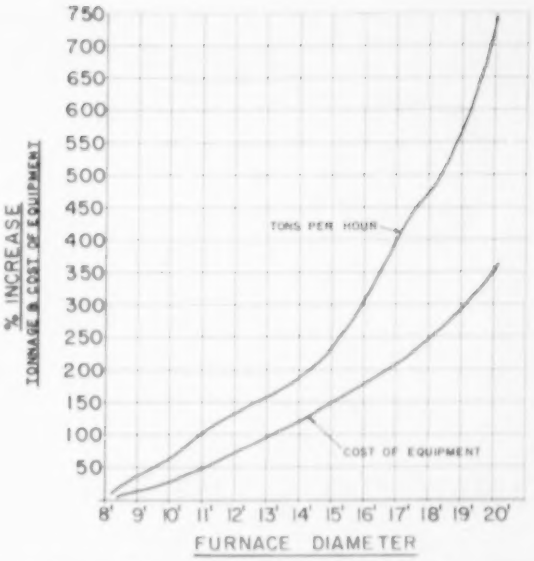
The percentage increase in electric furnace capacity since 1925 closely parallels the climb in total U. S. generating capacity during the same 30 year period. On the basis of relative dollar values, kwhr costs for the total electric consumption in the U. S. have decreased 33 pct since 1920, and, for the large industrial consumer, they are down to an average of 10 mils per kwhr, a decrease of more than 50 pct since 1937. Generally, industrial power costs have fluctuated between 9 and 10 mils per kwhr for the past four years, but indications are that further reductions are entirely possible through the introduction and advancement of new generating and distributing techniques.

Regarding metallics, the arc furnace is now favored in cold melting, because of the use of pig iron and selective scrap for the open hearth. The spread between the arc furnace's scrap charge and the expensive metallics of the cold melting open hearth charge should continue, because of the growing scarcity of high grade iron ore and the relatively high costs of taconites.

In hot metal practice, the arc furnace is just entering the field. Because of the high cost of thermal energy in the arc furnace, it would appear that it might currently stand to gain further from the use of hot metal that was melted with cheaper fuel. As fuel and power costs equalize, the trend to arc furnace duplexing should increase.

Development work for processing molten iron in the arc furnace is currently being carried on. One American electric-steelmaker has installed blast furnaces and is using a European method to rid the iron of impurities by a top blown method. Costs might be improved with a combination converter-arc furnace, whose electrodes could be swung aside to permit the blow of oxygen, and returned over the bath to adjust temperature and final analysis.

A 20-ton Swindell furnace is shown above, ready to be charged by a clamshell bucket.



As furnace diameters increase up to 20 ft, production goes up at a more rapid rate than does equipment cost. But as size increases beyond this point, production should begin to level off.

Furnace diameters are increasing to match open hearth capacities, and furnaces up to 24½-ft diam have been installed. As the size of furnaces and transformers increases, their cost increases proportionally at a given rate. It can readily be seen, however, that up to a certain point, production also increases, but at a much greater rate. There is an optimum diameter and input rate somewhere in the progression, where the production profits, as opposed to investment and operating costs, level off and finally descend.

There are indications that returns on larger diameter circular arc furnaces are not as promising as on 100-ton units, due to refractory expense, downtime, electrode consumption, and melting rate. Certainly there appears to be a definite limit on the melting effect of a three-electrode system on a furnace larger than 200-ton capacity. A close electrode circle on a unit larger than 25 ft diam would result in cold metal around the banks, and a normal electrode circle in proportion to diameter might result in poor melt-in characteristic. This, coupled with the fact that the impedance of extremely large furnaces results in dangerous secondary voltages, and long arc length, gives indication that it is entirely feasible that tomorrow's arc furnace of 200 tons or better might be a reversion to the elliptical shell with its six electrode system. Research and experience will point this up.

The need of arc furnaces in both the alloy and carbon fields is as acute as ever. Newer steel processes have certainly made their presence felt in estimating future arc furnace production. Yet, absolute control of temperature, better control and greater range of fuel input, control of atmosphere and alloy losses, better ability to deoxidize slag and metal, ability to shut down and start up at will, minimum space and labor requirements, and relatively low capital expenditure, forecast the growing future for the electric furnace that economic experts predict.

Economics of the use of virgin melting stock in electric furnace steelmaking is not only a matter of the relative cost of melting stock as charged. Possible savings also result from lower furnace operating costs, lower rolling, forging, and annealing costs, and improved customer relations resulting from a known and uniform quality steel. Producers know that a large portion of their problems would be solved by reducing residual content of their steel ingots to half the present levels and maintaining it at a known level. This desirable end can be achieved by use of virgin melting stocks.

Sponge Iron and H-Iron For Electric Furnace Charging

Based on a Paper by
P. E. Cavanagh

THE ideal charge for the melting and refining of all metals, from both the technical and quality control standpoint, consists only of virgin metal and return plant scrap. Steelmaking in electric furnaces is no exception to this general rule. But, in practice, the addition of purchased scrap metal to the charge results in more profitable operation, unless contamination of the finished metal by the scrap causes rejection of the finished product or serious difficulties in processing.

While it is generally true that scrap steel is a cheap source of iron for melting, the supply periodically becomes scarce and expensive. And under the present conditions of a rapid expansion of the steel industry, the price of scrap may become even higher than the price of virgin melting stock. In such times, there is intense interest in methods of producing and using virgin melting stock for steel making, and in comparing the relative merits of the different types of virgin melting stock available.

Virgin melting stocks can be divided into two categories: non-metallics, and metallics. In the first is iron ore, and in the second are pig iron, sponge iron, and lately H-iron. Each of these materials has specific advantages and disadvantages.

Non-metallic Charge—Iron Ore

In the electric steelmaking furnace the main disadvantage of iron ore as a melting stock is that it must be reduced from the oxide to metallic iron, and the electric steel furance is not designed or intended for this function. The result of using large amounts of ore in an electric furnace is excessive foaming, due to liberation of gas within the bath. While high grade iron ore is a cheap source of iron units for the charge, the maximum amount is strictly limited by the practical requirement of keeping the charge in the furnace. Nevertheless, processes have been developed in Europe for making steel directly from ore in electric furnaces, but these do not appear to be economic in this country.

Metallic Charge—Liquid Stock

Adding metal to the furnace in liquid form provides the most rapid and simple charging method, as well as the highest possible charge density. Molten charge also eliminates power needed to melt in the electric furnace. These factors contribute to high production rates and low power consumption.

Pig Iron—Melting sponge iron to make pig iron in the blast furnace slags off the residual gangue in the ore, which otherwise would have to be slagged off in the steelmaking furnace. As it melts, the sponge dissolves carbon from the coke to give a high carbon pig iron with the desirable feature of being handled at reasonably low temperatures; so, costs of handling and charging are relatively low. Pig iron is an excellent reducer of iron ore, but, unfortunately, bringing the two substances in contact in large quantities in an electric furnace is not practical.

P. E. CAVANAGH is Director, Dept. of Metallurgy, Ontario Research Foundation, Toronto. This paper is to be presented at the Electric Furnace Steel Conference, Chicago, December, 1956.

Table I. Recommended Analysis of Premium Grade Sponge Iron Melting Stock, Pct

	Sponge Iron	Required Ore Analysis
Pct reduction	90	
Total Iron	93.0	>67.0
Metallic iron	84.0	
C	0.70	
S	0.01	0.025
P	0.02	0.015
Mn	0.20	0.15
SiO_2	<2.0	2.0
Al_2O_3	1.0	0.7
CaO	1.0	0.7
Ti	<0.1	0.05
Ni, Cr, Cu, Zn, Sn, Pb	<0.01	0.01

[1] Final content can be controlled by the process.
[2] Determined by the chosen ore analysis.

Removing carbon from high-carbon pig iron charges in the electric furnace is costly and troublesome, even with oxygen lances. A reasonable percentage of pig iron in the charge provides efficient bath agitation during carbon removal, but it tends to delay tapping until some of the more sluggish reactions in the bath have been completed.

Blown Metal—It is possible to remove most carbon from pig iron by blowing in a bessemer converter. This results in a charge material more suitable for the electric furnace, but, unfortunately, the melting point rises as carbon decreases; so, the metal must be maintained at a much higher temperature, costing more than pig iron to hold and handle.

It is also possible to further purify pig iron and remove silicon and sulfur by treating in a ladle or converter, bringing these elements down to levels more acceptable as charge material. Such blown metal, desulfurized and desiliconized and with high density, is an excellent melting stock from the technical standpoint, in spite of the high temperatures at which it must be handled.

Metallic Charge—Solid Stock

Pig Iron—To most producers of electric furnace steel, discussion of molten charge metal is only of academic interest, since they have little prospect of providing such material for their furnaces. Solid pig iron is a more familiar material. It has all the disadvantages of molten pig iron, and, in addition, it is not at high temperatures and has considerably lower bulk density than hot metal. Pig iron is abundant and in relatively reliable supply.

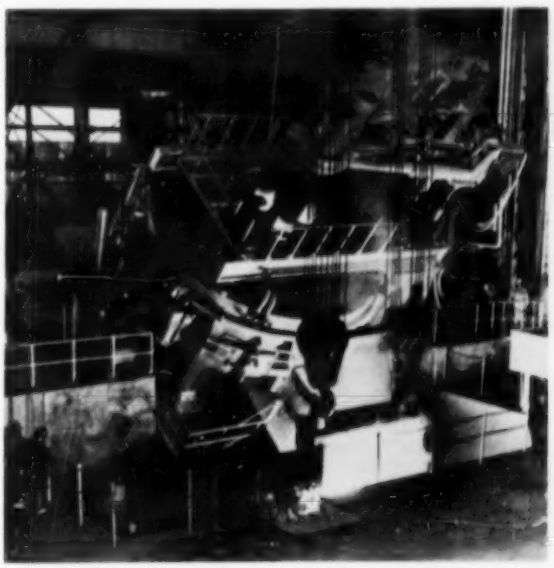
Sponge Iron—Today there is renewed interest in sponge iron as electric furnace melting stock in North America. This is because sponge iron can be made in favorable locations for $45 to $55 per ton of contained iron. Sponge differs from previously discussed virgin melting stocks in these features: 1) relatively low bulk density; 2) relatively low electrical conductivity; 3) residual iron oxide which must be reduced in the furnace; and 4) residual ore gangue which must be slagged off.

Sponge iron cannot be charged and melted in exactly the same way as scrap steel. A special charging technique should be considered for each type of sponge iron, depending on its density, conductivity, oxide and carbon content, and the nature of residual gangue materials.

Arriving at suitable economic specifications for sponge iron requires taking several factors into consideration. In reduction of iron ore, removal of the first 85 pct or so of the oxygen proceeds rapidly but becomes progressively slower as complete reduction is approached. It is, therefore, necessary to strike an economic balance between production rate of the sponge iron reduction furnace, the resulting cost of the sponge iron, and the cost of removing the residual oxide in the steel furnace. While sponge iron as low as 85 pct metallic iron has been processed in electric steel furnaces, 90 pct is a more satisfactory figure. Such sponge iron contains residual oxides, which can give a melt of about 0.30 pct carbon, if the sponge iron contains 0.70 pct carbon. The required carbon for a satisfactory melt-down is normally taken up by the sponge iron in the reduction process, but it may also be added by mixing with the sponge iron before charging. This means that the desired melt-down carbon must be specified and the required carbon in the sponge iron controlled with respect to remaining residual oxide.

A low-carbon sponge iron has a melting point of nearly 3000°F. If this sponge iron also has low density, it will have low electrical conductivity and be difficult to melt. Such a sponge iron is the least desirable type for general purpose melting stock. If it is not possible to introduce carbon during the reduction cycle, as is the case in hydrogen reduction, then the sponge iron should be compressed to higher density, or have carbon added, or both.

Specification of an allowable residual gangue content is again a matter for economic balance. There is a choice between purchasing a high grade iron ore, giving low residual gangue content which will require little slagging in the electric furnace, or in buying a cheaper, lower grade ore, which will result in high slagging and maintenance costs. Sponge iron as high as 13 pct SiO_2 has been used as melting stock in electric furnaces; so, the desirable upper limit is not a technical decision, but rather a matter of keeping maintenance costs within reason.



A 20-ft diam Lectromelt furnace being tapped. (Courtesy Lectromelt Furnace Co., Div. McGraw Electric Co.)

A satisfactory figure for silica content in sponge iron is about 2 pct.

The upper limit in the ratio of sponge iron to total metallic charge is reached when return plant scrap is the only other metallic charge. In such a case, the metallic charge might be 70 pct sponge iron and 30 pct plant scrap. Electric furnaces in Sweden have been running on such charges for many years. The actual percentage in a given case depends on costs. It is relatively simple to compare the costs of available sponge iron with purchased scrap, but it is difficult to assess the improvements in furnace production, yield, and savings in plant processing costs. Proper evaluation of sponge iron in any plant requires that trial heats be made over a period of time, using techniques dictated by the characteristics of the particular sponge used and products made. Swedish steel makers have so well recognized the benefits of sponge iron for making high quality steels in their furnaces that they are willing to pay more for sponge iron than for purchased scrap.

A Mexican steel company, Hojalata y Lamina, produces sponge iron and uses it in their electric furnaces to make rimming steel. Charges contain 45 pct sponge iron, and production costs are lower than when an all-scrap charge was used; production rate of the electric furnaces has increased about 5 pct and quality and uniformity have improved markedly.

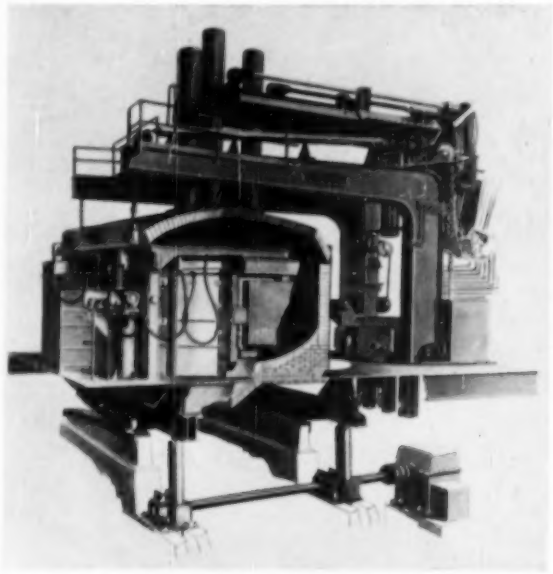
There is little value in giving details of charge compositions in various electric furnaces using sponge iron, since practice varies considerably, depending on products, characteristics of the available sponge, and the relative prices of other types of melting stock. There are no serious difficulties in using up to 70 pct sponge of the analysis shown in Table I, if the proper techniques are used.

Costs of Sponge Iron—There are three commercial methods for producing sponge iron for melting stock: the Wiberg-Soderfors process, the Tunnel Kiln or Hoganas process, and the Hojalata y Lamina natural gas process. Five Wiberg-Soderfors plants are operating in Sweden with a production of about 120,000 tons of sponge per year. A modified Hoganas process is in operation at Oxelosund, Sweden, and a Tunnel Kiln process is going at Hojalata y Lamina in Mexico; together they have a capacity of about 60,000 tons a year. The Hojalata y Lamina natural gas process is producing some 30,000 tons per year. In the U.S. there is also a Hoganas kiln in operation at Riverton, N.J., making sponge iron for iron powder production.

Production costs, ranging from $45 to $55 per ton of contained iron, depend largely on raw material, fuel, and power costs. For a given grade of ore, there are only minor differences in costs of labor and maintenance for the various processes. Capital costs vary considerably from one process to another, with the Tunnel Kiln process providing the lowest investment.

A major difference in production costs is due to the cost of reducing gas. In all sponge iron processes, reduction is effected by a gas generated from coke, coal, oil, or natural gas. The Wilberg-Soderfors furnace utilizes coke and electric power to generate a mixture of hydrogen and carbon-monoxide. Power at about $0.01 per kwhr and coke at about $17 per ton are required to achieve a sponge cost within the $45 to $55 range. It should also be possible to operate the Wiberg-Soderfors process successfully by adding natural gas to the present carburetors, or by using gas produced from natural gas or oil. The Mexican process utilizes natural gas alone, and the Tunnel Kiln process generates gas from coal or coke.

H-Iron—H-Iron is a type of sponge iron, whose characteristics can be controlled within limits to improve its suitability as a virgin melting stock for steel making. Hydro-Carbon Research Corp. has recently released information on the H-Iron process they are developing. This process has been operating on a pilot-scale to produce a low-carbon, low-density, sponge iron. The product is made more suitable as a charging material by compressing it in rolls and breaking it into chips.



Cutaway drawing of a modern Héroult electric melting furnace. (Courtesy American Bridge Div., U. S. Steel Corp.)

This process represents the first time that the fluidized bed technique has been satisfactorily applied to iron reduction. It has proven extremely difficult to maintain a bed of fine ore in a fluidized condition at temperatures of 1800°F while being reduced. The partially reduced sponge iron tends to agglomerate and settle out of the bed, so that fluidizing soon stops. But the H-Iron process has demonstrated that by operating in hydrogen at about 900°F under high pressure, a bed of fine ore can be maintained in fluidized condition during reduction. The relatively low temperature tends to slow down reduction reactions, but this is more than compensated by the accelerating effect obtained by the fluidized bed.

Cost of reducing gas is again the major variable in the cost of H-Iron. Production costs per ton of contained iron will fall within the range of $45 to $55, if the cost of natural gas used for making the reducing gas is lower than $0.50 per thousand cu ft.

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Desiliconized Pig Iron For the Electric Furnace—A Possibility

Hot-charging of pig iron into the electric furnace is a subject of much interest. The advantages of desiliconizing the pig before charging, as here presented, make an important difference in costs.

by S. L. Case

AN investigation of the comparative economics of open-hearth and electric furnaces for production of low-carbon steel, published in 1953,[1] showed that, in an integrated steel plant, the economics of the electric furnace as a steelmaking unit compared favorably with those of an open hearth. It was pointed out, however, that the problem of operating an electric furnace on a charge containing a high percentage of hot metal hasn't been solved as yet. One of the important stumbling blocks in such an operation is the high silicon content of the charge, when the ratio of hot metal to scrap is 1 to 1, or higher.

Each pound of silicon added to the furnace charge produces over 2 lb of silica, which in turn requires about 6 lb of lime to produce a slag of desirable characteristics. If the SiO_2 content of the furnace slag at the final stage of refining averages about 15 pct, the slag volume resulting from each 0.1 pct of Si in the 50-ton hot-metal charge will approximate 1500 lb. It is, thus, evident that, if the hot metal were desiliconized as a preliminary step to charging into the furnace, the amount of slag carried by the bath would be greatly reduced. As an example, if the desiliconization could reduce the silicon content of the hot metal by 0.7 pct, slag volume in a 100-ton heat would be reduced by about 10,500 lb. Also, 4200 lb of burned lime could be saved on each heat, and ingot yield would be substantially increased, because the slag carries from 12 to 20 pct FeO, depending on the grade of steel being made. Reduced volume of slag will also result in decreased consumption of electrical energy.

A very informative paper on the economics of desiliconization in electric-furnace steelmaking was published by E. C. Wright in January, 1956.[2] Wright bases his calculations of material and heat balances on the premise that standard hot metal contains 4.0 pct C and 1.0 pct Si, and that desiliconized or *washed* hot metal contains 2.0 pct C and 0.1 pct Si. Insofar as electrical energy requirements are concerned, Wright's calculations show that on a 50:50 hot-metal charge, use of desiliconized iron will reduce electrical energy requirements by about 63 pct —456 kwhr per ton of liquid steel for *standard* hot-metal charge vs. 289 kwhr for a *washed* hot-metal charge. With nearly all of the silicon and about half of the carbon in the metal being removed by the desiliconization treatment, it should be possible to operate the electric furnace on a higher ratio of hot metal to scrap in the charge. Under such a practice, the saving in electrical energy requirements should be even greater than for the 50:50 practice. For 60:40 and 70:30 ratios of hot metal to scrap, Wright's calculated energy requirements are 248 and 220 kwhr per ton of liquid steel, respectively, assuming a 70 pct efficiency.

Regardless of what process is employed, desiliconization of hot metal for electric furnaces will probably be considered a *must* in the near future, when operation of electric furnaces on a high hot-metal charge may be expected to become common practice in integrated steel plants. Costs of desiliconization are estimated to range from $1 to $2 per ton of hot metal. This would be compensated many fold by savings in lime, electrical energy, electrodes, and increased furnace output. Wright[2] estimates that on a charge of 60 pct washed hot metal and 40 pct scrap, melting rate in a 100-ton electric furnace would approximate 40 tph, while on a conventional charge, the hourly output of a similar furnace would, under optimum conditions, average only 24 tons.

The figures cited above give a favorable outlook for desiliconization treatments of hot metal in electric-furnace steelmaking. It should, however, be borne in mind that, up to the present time, there are no reported data on the use of as much as 70 pct hot metal in the electric-furnace charge. Therefore, the desiliconization effects discussed are predictions and extrapolations. There may be some operating complications when electric furnaces are operated on a hot metal charge containing only 0.1 pct silicon, but such complications are not obvious at the present time. What is now known about the so-called duplex open-hearth practice, indicates that the extremely low slag volume of the duplex process does not lead to any dephosporization difficulties, except in rare instances of ladle rephosphorization on high-carbon, thoroughly deoxidized steel, but such difficulties can be readily prevented by a high V-ratio in the slag.

S. L. CASE is with the Battelle Memorial Institute, Columbus, Ohio. This paper to be presented at the Electric Furnace Steel Conference, Chicago, December, 1956.

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High Alumina Ladle Linings

by V. J. Howard

CHANGES in plant operation at Oklahoma Steel Castings Co. raised average metal tapping temperatures. A search for a ladle material more refractory than ganister was prompted by an increasing amount of surface slag defects and nonmetallic inclusions in the castings, as well as decreasing ladle life. It was necessary to find a material that would not erode the downspout and would hold the inspout to close tolerances in order to retain furnace and ladle slags. After numerous trials, an 80 pct alumina-18 pct silica material was selected.

Ganister had been used successfully for years at the previous temperature level, and alumina had not been employed, because it was felt that use of high alumina, with its 3350°F service limit, was not economical unless dealing with metal temperatures high enough to give deep vitrification.

Ladles at the plant are of the 4-ton teapot type, with 3½-in. downspout and 3-in. inspout. Sidewalls are rammed without brick backing to a 4-in. thickness. Heats poured through these ladles are 7700 lb. A change in the weight distribution in the plant resulted in 30 pct of production being poured through 270 lb monorail pots. This, along with increased production of shell molds, raised average tapping temperatures from 3019° to 3071°F, and many heats were required above 3100°F. Furthermore, low-carbon, high-alloy production increased from an occasional heat to about 5 pct of total production.

Success of the ladle linings depends a great deal on the method of application. Obtaining a dense ram with adequate penetration at the parting is essential. High alumina should be rammed as dense as possible, using care to see that no voids are left in the rammed structure where metal might penetrate. Also, some device should be used to rough up the rammed surface, so that the next layer knits better, helping to prevent laminations.

Fig. 1 shows a section taken from one of the early attempts at high alumina linings; the lamination of each layer stands out clearly. This example serves as a reminder of the importance of density and impregnation of the joints. Fig. 2, a side view of the same section, shows how metal attacks the laminated area. It also indicates the depth of the heat affected area. In spite of this poor ram job, the ladle from which this sample was taken gave twice the life of an average ganister ladle, life being determined by the amount of erosion either in the spout or body. Wall thickness is measured with calipers, and a good margin of safety is maintained.

Air pressure at the rammer should be 95 to 100 lb in order to give good ramming impact from the guns. Fig. 3 shows the alternate rammer used to penetrate, or key the surface after it has been thoroughly rammed with a flat-headed No. 4 floor rammer into a 2-in. layer. The tips employed are ⅜-in. rods, ¾-in. long; they are used until they wear down to ½ in. Fig. 4 is a section taken from the spout of a ladle rammed with this device.

Title Fig. is a ladle completely rammed, immediately after the forms were removed. It shows the light-colored high alumina used in the retaining wall to decrease erosion while tapping from the furnace into the ladle. This ladle is air dried for 18 hr before it is washed with a heat setting cement and torch dried for 24 hr. Drying and preheating the material is important, because high alumina will

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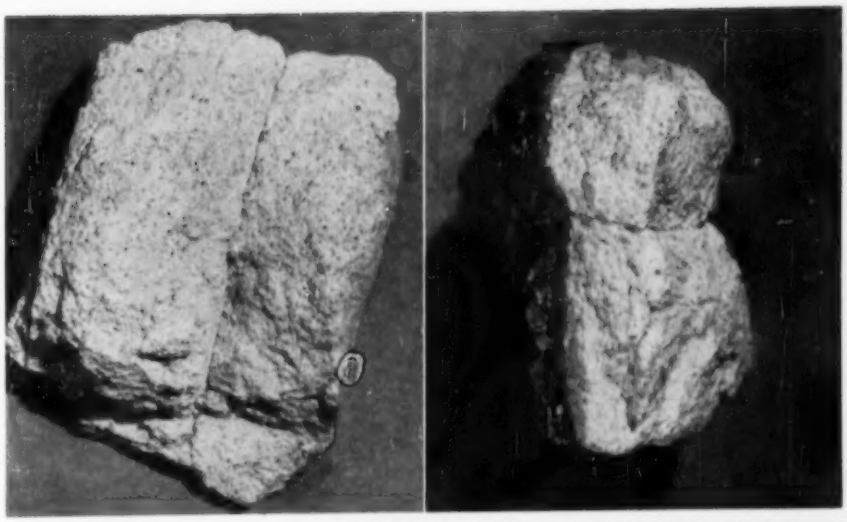

Fig. 1—Left—This is a section taken from an early alumina ladle lining. The laminations serve to emphasize the importance of density of impregnation.
Fig. 2—Right—This side view of the same area shows how metal attacks the laminated area of alumina linings.

form a high ceramic bond and a deeper vitrification zone, if elevated temperatures are attained before the metal comes in contact with the alumina lining. After torch drying the entire ladle, the spout is fired with an air-natural gas mixture for 6 hr while torch drying continues in the ladle body. Then the ladle is placed on the ladle wall where it is preheated for 2 hr. As a further step to deepen the heat affected area, it is required that the first heat tapped into the newly rammed ladle shall exceed 3150°F.

Table I shows a cost comparison for direct labor and material. The high alumina represents an increase of $0.033 per ton of metal poured. But it is felt that the variables not included in these costs, such as material handling, equipment, gas, and space and time needed for drying and preheating the extra ladles if ganister were used, would more than equalize the cost. The high alumina spout poured two and a half times the amount of metal poured by the ganister spout. Furthermore, when slag weld and scrap enter into the economic picture, the $0.033 per ton seems insignificant. Slag weld has definitely decreased, and the savings there will far exceed anything spent on refractories.

Summary

When handling high temperature metals, the advantages of high alumina are: low shrinkage, high strength, high density, and high temperature resistance.

The disadvantages are: high refractoriness, if the metal temperatures are below 3000°F, and the problems encountered in ramming procedures. Proper ramming technique and fixing at high temperature before using the ladle are essential to bring this material into optimum condition.

Table I. Economic Comparison of Ganister and High Alumina Refractory

	Ganister	High Alumina
Materials cost per lining	$ 26.28	$106.55
Labor cost per lining	15.50	14.49
Total Cost	$41.78	$121.04
Tons of metal poured per lining	165.4	423.5
Lining cost per ton of metal poured	$ 0.253	$ 0.286

Fig. 3—Alternate rammer used to penetrate ladle lining surface after it has been thoroughly rammed.

Fig. 4—A section from the spout of a ladle rammed with the device shown above.

Zircon Ladle Linings

For Cleaner, Low Cost Metal . . .

by W. D. Emmett and V. E. Zang

MOLTEN metal is in contact with ladle linings at a critical point in its handling. These linings can break down into a fluid slag and be carried into the mold cavity—thus causing surface defects; or some of the slag may be trapped in the metal as nonmetallic inclusions. Therefore, the initial cost of a lining is of secondary importance when slagging of the ladle can be prevented. There are two major causes of linings eroding to the extent that they become a liquid slag. First, the melting points of basic ladle linings are lowered by silica from furnace slag, and second, melting points of acid linings are lowered by iron oxide from furnace slag.

Linings composed of silica sands, quartzite, gannister, etc. have a high expansion at elevated temperatures. While the lining is plastic this expansion has little detrimental effect if enough bonding clays are incorporated to control expansion. However, upon cooling to 447°F cristobalite reverses itself, and a sudden contraction of 2.8 pct volume change takes place. This results in the formation of small hair line cracks, which are usually encountered in monolithic linings.

C. Wyman[1] states that the more closely a solid mass can be approached, the greater is the efficiency that can be expected from a ladle. A material of high refractory and low expansion values, not affected by iron oxide or silica, should be chosen. Then, by balancing the particle size to attain high packing density, and using no more binder than necessary, a solid erosion-resistant mass can be approached. This binder[2] should contain low fusion point materials or a combination of materials which form low melting point eutectics. To this should be added a finely divided material, which is soluble in the melted bond, and which will raise the melting point when once dissolved.

Maximum Density Necessary

A combination of zirconite* sand and flour, so mixed as to obtain the maximum density possible, and bonded with a small amount of sodium silicate and fire clay, is an excellent monolithic lining. No attempt is made to give the proper sand-to-flour ratio, as it has been found that each shipment of sand and flour has a different particle size.

Care must be used in purchasing a zirconite sand, as there are two ways of processing it—one, oil flotation, and the other, electrostatic. The oil flotation method coats the sand with a thin film of oil. Although this sand is slightly less expensive, it cannot be successfully bonded, and a ladle lined with this sand will show poor results. A simple test for oil flotation sand is to spread the sand on the surface of distilled water—if some sand floats, it was processed by oil flotation; if electrostatic process was used, the sand will immediately drop to the bottom.

The inner shell of a ladle is lined with ⅛ in. asbestos paper to prevent heat transfer to the sides and bottom. Zirconite has a higher heat transfer rate than either silica or clay, and if asbestos or some other material is not used as an insu'ation, the shell soon becomes uncomfortably warm.

The mixture should be rammed around a steel form for both small and large ladles, and compaction should be done evenly so that no soft spots are left in the lining. The mix, being very fluid, requires little ramming to pack to its greatest density. Care must be taken not to over-ram, and not more than 2 in. should be rammed at one time, scoring between each ram. After the form is drawn, the ladle should be swabbed with a 30 Bé sodium silicate wash.

Slag build-up on the lining of a 600 lb ladle after 80 heats.

Firing Procedure

After washing, the ladle should be fired immediately in an upright position, as this material has small green strength. The initial firing should be at a low heat for 48 hr, and final firing should be for 72 hr at the highest possible temperature. This may seem to be a considerable length of time for firing, but it must be remembered that this mix is dense

Table I. Cost Comparison of Brick and Zirconite

Cost of materials and labor used in lining a 7-ton ladle:	
Brick lining	$108.44
Zirconite lining	$502.36
Avg life of two linings:	
Brick lining	42 heats
Zirconite lining	600 heats
Cost of lining per ton:	
Brick lining	$0.40 per ton
Zirconite lining	$0.12 per ton

* Zirconite is the registered trademark of the Titanium Alloy Mfg. Div. National Lead Co.

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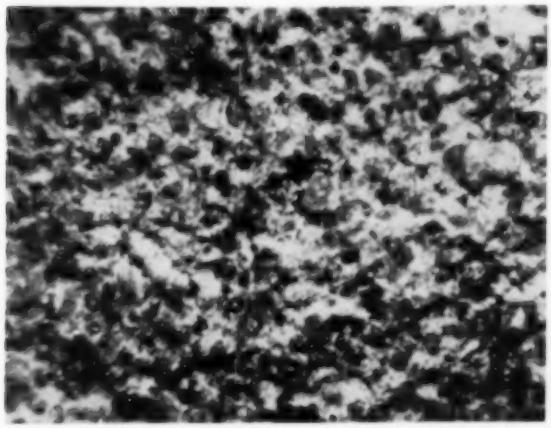
and under-firing will cause either metal trouble or loss of ladle life.

Small ladles—300 to 1000 lb capacity—have been used for 80 heats and large ladles—12,000 to 16,000 lb capacity—have been in use for over 600 heats. One teapot spout rammed with this mix was used for 1300 heats before being renewed. A teapot ladle must be fired in both the pouring spout and the bowl to prevent oxidation of the neck between spout and bowl.

This mix will withstand little impact in a cold condition. Therefore, ladles must be cleaned of slag in a red condition to prevent small hairline cracks from appearing in the lining of the ladle. Erosion will start at these points with resultant shortening of ladle life. Furnaces should be tapped so that the stream does not impinge against the side wall of the ladle; otherwise the impact of the metal will wear a groove in the side of the ladle.



A magnified cross-section of a monolithic ladle lining made from the zirconite sand-flour mixture. Note the high compaction. Mag. 27X.

Thirteen-ton, bottom pour ladles were rammed with this mix, and the results were disappointing. Metal tapped into a bottom pour ladle is usually much colder than that which is tapped into a teapot or system ladle, with the result that after pouring, a skull forms on the bottom and on the sidewall adjacent to the bottom. So far, no way has been found to remove this skull without impact when the ladle is in a cold condition, and continued impact causes the lining to shatter. Oxygen has been used to remove the skull, but the reaction between the oxygen stream and the zirconite lining is very high and results in channels being cut in the sidewalls and bottom.

Conclusions

The zirconite lining has both good and bad features. On the bad side, 1) ladles are not easily kept clean of adhering slag; and 2) the mix *sets up* very hard, causing a greater length of time to knock out.

Zirconite is credited with these features: 1) longer ladle life; 2) considerable savings in cost of lining per ton of metal poured; and 3) cleaner metal.

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. . . In Basic Electric Furnace Practice

by W. A. Koppi

ZIRCON may show a difference in behavior when used as a refractory for handling hot metal made by the acid and basic processes. Investigations by Zang and Grott[1] of Unitcast, Blosjo of Minneapolis Electric Steel, and others, have shown that zircon performs quite satisfactorily when handling acid steel. Ladle campaigns with zircon linings have been reported in the order of hundreds of heats for acid steel, but experience in the production of basic steel at Lebanon Steel Foundry has not measured up to this performance. While basic ladle life is found to be lower, it is only a reflection of unit refractory cost, and not a full appraisal of the value of zircon.

The Material

Zircon, the zirconium silicate—$ZrSiO_4$—has long been recognized as a highly refractory material. However, its development as a monolithic refractory for practical use in handling hot metal has progressed slowly, the problem being to find a suitable binder to resist chemical attack at relatively high temperatures. As was found in the investigation by Zang and Grott,[1] small additions of fireclay and waterglass make a bond that is quite serviceable.

Zircon is the product of a peritectic reaction; consequently, it remains quite stable until it reaches a temperature around 3200°F. Then it commences to dissociate into solid zirconium oxide and a liquid solution, which is primarily silica with a small amount of dissolved zirconia. In view of this dissociation, with respect to the ceramic bond, it would seem that the use of zircon at temperatures above

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Table I. Component Materials of Zircon Mix

Material	Pct	Lb per Batch
#100 Zircon Sand	80.00	1,540
#120 Zircon Flour	15.60	300
Fireclay	3.10	60
*Waterglass (Bé 41°)	1.30	9 qts.
Moisture	3.3 to 3.5	7.5 gal.

* $\frac{Na_2O}{SiO_2} = \frac{1}{3.22}$

Mulling cycle: 1 min dry mull
4 min wet mull

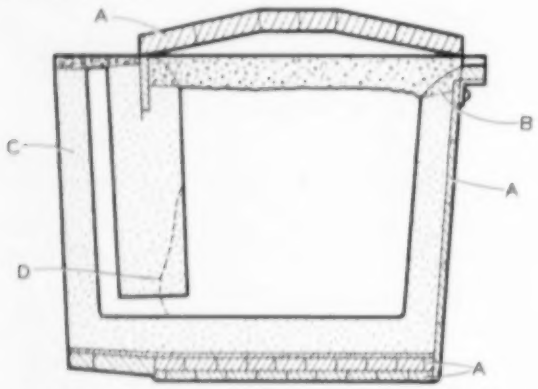
The fireclay splits are Woodland high-duty aluminous fireclay, having a P.C.E. of 31-33.

3200°F is questionable, especially if time at temperature is of any duration.

Chemically, zircon is acidic. However, below its transition temperature it appears quite stable when in contact with slags of low basicity. This characteristic, along with a low coefficient of expansion and contraction, suggests that zircon may have some merit as a monolithic lining material for handling basic steel at temperatures below 3200°F.

Hot Metal Handling

At Lebanon Steel Foundry's carbon shop there are two Swindell arc furnaces, having shells 8-ft in diam and producing nominal heat weights of 8500 lb in plain carbon, and low and high alloy steels, by the basic single-slag process. Approximately 70 pct of these heats are shanked, while the balance are bottom poured.



Refractory structure of teapot bull ladle: A—fireclay brick; B—chrome plastic; C—zircon; and D—critical area of greatest wear.

Shank heats are normally tapped at temperatures of 3100° to 3200°F into bull ladles of teapot design, having a capacity of 9000 lb. Immediately after tap, the greater portion of the basic slag, which has a basicity of 2.0 — 2.8, is removed by pouring off over the slag-off lip. Slag remaining in the ladle is diluted with dry reclaimed foundry sand to lower basicity to about 1.0, thus minimizing chemical attack on the zircon lining. A cover is then mounted on the bull ladle which is subsequently conveyed about 300 ft to a pouring station, where it is transferred to a stationary jib hoist. Hot metal is poured from the bull ladle into 1000 lb shank ladles, which also are of teapot design.

Bull Ladle Refractories

The bull ladles have a monolithic lining of zircon, which is backed up with fireclay splits and capped with a plastic chrome mix. The zircon mix used is a modification of that developed by Zang and Grott;[1] it is made-up of the materials shown on Table I. The plastic chrome mix, on the other hand, is a commercial product, which, when tempered with water, makes a readily workable plastic that sets up hard upon drying.

Performance

The average lining life for this type of lining is approximately 50 heats. Campaigns with less than 50 heats are usually the result of: 1) low ramming density; 2) interfacial planes of weakness where adjacent layers join together; 3) neglect in firing the lining immediately after it has been installed; 4) prolonged interruption during the ramming process; or 5) contamination of the mix at the muller.

Before covers were installed to retard the loss of heat during the pouring cycle, adherence of slag to the sidewall posed a problem. Slag would become mushy and difficult to drain at the completion of the pour. This feature is undesirable, as the slag is difficult to remove once it solidifies, and consequently, it becomes a source of contamination for subsequent heats. It also tends to obscure defective areas in the lining, thereby making lining condition difficult to evaluate satisfactorily.

The degree of chemical attack by slags with reduced basicity is negligible. Lining thickness in the areas not subjected to severe erosion shows little change in wall thickness. But slags of higher basicities have resulted in greater attack on the sidewall, especially in the areas of severe erosion.

While all shank heats are tapped near the transition temperature of zircon, there is an immediate temperature drop of approximately 150°F. This drop in temperature at tap minimizes the thermal breakdown of zircon. This is borne out by the negligible change in lining thickness at the end of the campaign.

Maintenance

Little maintenance is required throughout the lining campaign. In some instances, a new spout section leading from the bowl of the ladle may be installed, if there is evidence of excessive wear during the early stages of the campaign. Basic slag from the tap may hang up around the top of the ladle, but this is readily removed by allowing the slag to hydrate upon cooling.

Economics

Total refractory cost to line a teapot bull ladle is about $0.85 per ton of steel handled. This includes labor cost for installation and intermittent maintenance. When silica linings were used, the cost to handle a ton of steel was approximately $0.45.

Conclusion

Although the zircon refractory may be acid in nature, through proper control it has shown a satisfactory level of performance when used in basic steel making. While this performance level in the Lebanon Steel Foundry shop is only 50 heats per lining, it is believed that this could be substantially increased, if the bull ladles could be properly placed in the pits to minimize erosion. Superior refractoriness and negligible coefficient of expansion of zircon place it above many available siliceous materials. These same properties also make it a strong competitor to many basic refractories, which, for certain features, have limited applications. Its cost may, at first, appear prohibitive, but its true value can only be ascertained by a measure of casting quality.

Since converting from a silica lining to the present zircon lining, Lebanon Steel Foundry has noticed an over-all improvement in casting quality in the carbon shop, i.e. less exogenous inclusions. Zircon may not be the complete answer to the hot metal handling problem, but it has yielded hot metal with less slag formation from ladle linings.

Reference

[1] Zang & Grott: *Steel Foundry Facts*, April, 1955

The Cyclical Movement of Steel Scrap Prices

Based on an Article
by Chapin Hoskins

Since 1948, a continuous study of the price of scrap steel has been carried on at the Institute for Trend Research (ITR) under the sponsorship of Lukens Steel Co.

The present informal report on cycles in the price of steel scrap shows what can be learned when fluctuations in price are studied somewhat as the background of an engineering problem is studied.

IN the ITR studies of steel scrap behavior, American Metal Market monthly and Iron Age weekly prices from 1901 to the present time have been used. Statements in this report are based on monthly prices of Number One Heavy Melting at Pittsburgh.

In the first quarter of the present century, Pittsburgh Number One Heavy Melting once sold at around $10 a ton and once at nearly $41; in the second quarter century, its extremes were $8 and $46; during 1956 it has reached $58. Thus, we can begin with a statement that the price of scrap rises and falls over periods of time and then proceed to the very simplest definition of a cycle in scrap price, namely: a cycle is a rise followed by a decline. More precisely stated, a scrap price cycle is a wave in which monetary value is a vertical dimension and time is the horizontal dimension. For convenience the cycle can be measured from low point to low point, although other points of measure are possible.

The structure of waves in steel scrap price is such that waves of one approximate dimension are most obvious, but these are really riding on the backs of still larger waves, and their own surfaces are ruffled by smaller waves.

Minor Waves: Among the rippling waves in scrap price, one type is seasonal in nature; in general, this is a semiannual movement. Usually it can be observed only at times when the force of larger cyclical movement is slight. But there are also other minor waves of a nonseasonal nature.

Major Waves: The greatest discernible wave in scrap price is delineated by a decline of 54 pct between 1902 and 1914, a rise of 303 pct from then to 1917, a decline of 80 pct into 1932, and a rise of 604 pct since then. This wave is clearly associated with the coming and going of war and peace.

The Operating Cycle

In between the major waves and the minor waves in both horizontal and vertical dimensions is a class of wave in scrap price which we can conveniently call *The Operating Cycle*. A wave of this character tends to last approximately two, three, or four years, but in time of war, it may last longer than four years.

A simple characteristic of this cycle is that at its beginning, the price of scrap has always been lower than it was a year earlier; at its crest the price is higher than a year earlier; and at its end the price is again lower than a year before the end.

Between 1900 and 1954 there were 17 such cycles. In the majority of these the price rose 45 pct or more in one year; in a third of them more than 65 pct. In the declining phases of the 17 cycles, the price has, in a majority of cases, fallen 31 pct or more in one year; see Fig. 1.

Clearly, the extent of these rises and declines and their importance to users and providers of scrap make this a cycle of great importance to those with operating or executive responsibilities. This is why it has been dubbed The Operating Cycle.

Measuring and Observing the Cycle: An effective way to measure cyclical price change is to compute a continuous record of its rate of change. This means dividing the amount of change—the vertical wave component—by a unit of time—the horizontal wave component. Thus, it is possible to calculate change per year, per decade, per month, per week, or per any other chosen span of time.

Rate of change per 12 months is a particularly useful measure for the identification of cycles of two to four years. One reason is that this measure nullifies the effect of price changes that may be purely seasonal.

Engineers will recognize this simple calculation as a *first derivative*. In constructing a 12-month rate of change series for Pittsburgh scrap, the price at January, 1902 was divided by the price at January, 1901, the February, 1902 price by the February, 1901 price, and so on. The resulting percentage in each case is, in our language, a *1/12 pressure*.

In Fig. 2 is shown a sample operating cycle, with the actual price variation in the top portion and the cycle in terms of 1/12 pressure at the bottom.

During its progress, the rate of change cycle, shown in Fig. 2, passed through four phases:

Phase	Position of Price	Rate of Change	Length in Months
A	Below previous year	Rising	9
B	Above previous year	Rising	3
C	Above previous year	Declining	16
D	Below previous year	Declining	7
		Total	35

This can be considered a specimen cycle, but, although no two cycles are exactly alike, these general statements can be made:

CHAPIN HOSKINS is Chairman of the Trustees of the Institute for Trend Research, Hopkinton, N. H. This paper is to be presented at the Electric Furnace Steel Conference, Chicago, December 1956.

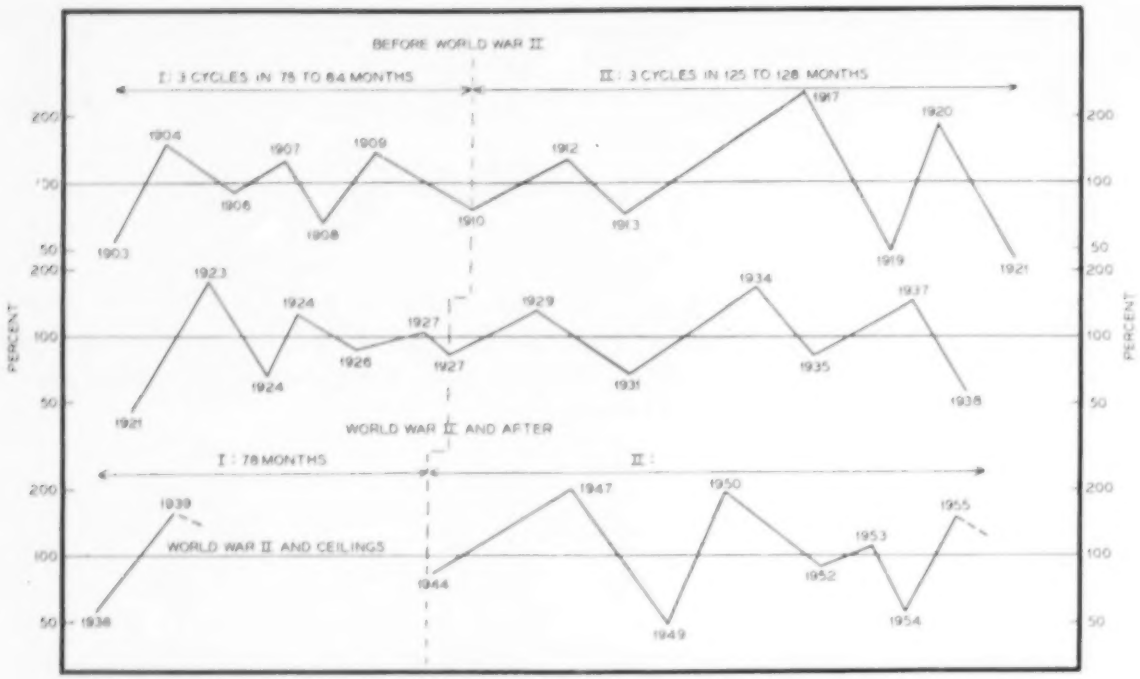


Fig. 1—Between 1900 and 1954 there were 17 Operating Cycles, each lasting from 2 to 4 years. Shown is a 12-month rate of change series for Number One Heavy Melting scrap at Pittsburgh.

1) For more than 50 years, except during the period of wartime price ceilings, scrap price has experienced a succession of such cycles;

2) All 17 recorded cycles have passed through all of the ABCD phases;

3) In peacetime, no cycle has been more than 46 months long. This means that no period of four years has gone by without scrap passing at least once through all four ABCD phases; and

4) No cycle has lasted less than 20 months (virtually two years).

Dynamics of Cyclical Change

In all 17 of the scrap cycles, Phase A has been followed by Phase B. This seems to mean that, once the rate of change has begun to rise, after a Phase D, forces have been set in motion which will, within a number of months, drive the price higher than it was a year earlier. Phase B has always been followed by Phase C, and Phase C by Phase D.

Dynamic Details: From its beginning to its end, each cycle in scrap price appears to be subject to dynamic laws just as definite as a wave motion in a physical body.

The length of Phase A depends greatly on how long the rate of change has remained in Phase D. The relation is so close that, if in 16 cases the length of Phase D is taken and a constant of 3 months subtracted, then in nine cases a median error of 1 month and a maximum error of 2 months is made in calculating the length of Phase A.

Furthermore, the amplitude—depth—of Phase D appears to influence the amplitude—height—of Phase B. Therefore, Phase D has an important bearing on what happens during the next 12 months or more, because the crest of Phase B is rarely reached in less than 12 months after the end of Phase D.

Actually, the influence of Phase D extends farther than 12 months. Out of the 17 recorded cases: in the four cycles which had the highest amplitude, the median-average length of Phase C was 11½ months; in the four cycles rising next highest, the median-average length of C was 8½ months; the cycles which ranked 10 to 13 in amplitude had Phase C's with a median-average of 7½ months; and in the four cycles of least amplitude, the median-average of Phase C was only 1½ months. Conformity is sufficient to justify a general statement of tendency: The higher the pressure rise in Phase B, the greater the length of Phase C.

Thus, it will be seen that the influence of Phase D extends at least to the end of the next Phase C. This, it will be remembered, is the point at which the price again falls below that of a year earlier. And, since in the majority of cycles the end of Phase C has occurred more than two years after the beginning of the cycle, it will be seen that conditions at the start of the cycle are likely to show their mark for at least that length of time.

These examples of scrap steel price dynamics suggest the existence of what might be considered potential energy at the bottom and the top of each cycle. Actually, the situation at every step in the cycle appears to have a bearing on the timing and amplitude of future change.

But what about economic conditions, the supply of and demand for scrap, and so on? Surely these are the primary factors in the rise and fall of scrap prices.

Two statements are suggested for consideration:

1) The influences of supply and demand normally operate within limits set by price dynamics. These influences tend to modify dynamic trends, but only under very unusual conditions can they completely alter them; and

2) The supply situation and the demand situation at any given time are themselves largely the results of dynamic situations and previous dynamic change.

Are Scrap Cycles Periodic?

There is considerable evidence that the rate of change cycles in steel scrap price tend to be periodic. The periodicity is not simple but compounded of periods of different length. This can be clearly observed on an ITR Time Chart,[1] but can be only broadly described here.

Two of the most serious 1/12 pressure declines in scrap price ended in December, 1903 and in April, 1938. These points of time were 412 months apart.

Two of the most violent rises ended in December, 1904 and October, 1939. These were 418 months apart.

Two other violent pressure rises ended in October, 1912 and August, 1947. These were also 418 months apart.

The low following the Armistice of World War I was 420 months before the low following the Korean Armistice.

All of these intervals, it will be seen, are not far from 416 months, and very nearly all of the 136 simple and compound intervals between the beginnings and ends of 16 cycles could be harmonically related to an interval of approximately 416 months. Traces of other periodic tendencies appear in the time charts, but the 416 months harmonic tendency seems by far the most important.

The interesting way in which these harmonics appear to combine can be simply illustrated by a synopsis of what has happened in each 17 1/3 years of the record (17 1/3 years, 208 months, or half of 416 months).

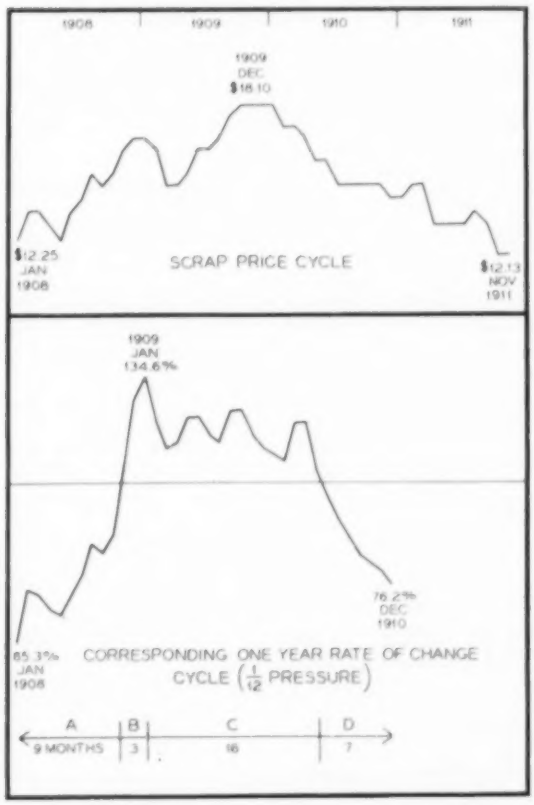


Fig. 2—A sample Operating Cycle, with actual price variation shown above and the cycle in terms of 1/12 pressure below.

The first complete 1/12 cycle began in December 1903. In December 1910, 84 months later, three cycles had been completed, with an average length of 28 months. In the next 128 months, to August 1921, three more cycles had been completed, this time with an average length of 42 2/3 months. The total period of these six cycles was 212 months.

After August 1921 three cycles occurred in 75 months. The end of these cycles averaging 25 months was in November 1927, 203 months after the end of the three previous short cycles.

Following 1927, three more cycles ended in April 1938. These occupied 125 months, averaged 41 2/3 months, and were completed 200 months after the three previous long cycles.

In summary, the 412 months following December 1903 contained three cycles averaging 28 months, then three averaging 42 2/3, next three averaging 25 months, and finally three of 41 2/3 average. Twenty six months, it will be noted, is one-eighth and 41 2/3 is one fifth of 208 months. The period of 84 months is also approximately two periods of 41 2/3 months.

In the 208 months since 1938, this pattern was interrupted by World War II and by ceiling prices after the peak of the first cycle. It appeared to resume at the end of the war and was again interrupted by the Korean conflict, ceilings, and armistice.

Scrap Price Cycles and Others

It would scarcely be supposed that scrap price cycles are an isolated phenomenon; they are not. Rate of change cycles occur in business activity and in the price of practically every unadministered commodity.

The Institute for Trend Research maintains a cyclical barometer which is a measure of the central tendency of rate of change in 15 different volume and dollar measurement series. In 5 out of 11 comparable cycles, the pressure rise in scrap steel has started at the same time as or one month sooner or later than a rise in the barometer. The relation at the cyclical high is not as close.

In a majority of 13 comparable cycles, the upturn in scrap price (1/12 Phase A) began from 7 months earlier to one month later than that of steel operations.

In minor cycles measured in weeks, cycles in steel scrap price usually correspond to cycles in the average price of metals.

Summary

1) For over 50 years scrap steel price has risen and fallen cyclically.

2) Its cyclical movement is compound of cycles which can be measured in years, others which are best measured in months, and some which must be measured in weeks.

3) Cycles can be effectively measured in terms of rate of change.

4) There appear to be definite laws governing cyclical change.

5) There is evidence of periodic tendencies in rate-of-change cycles.

6) Cycles in scrap price are related to cycles in other prices and in activity.

References

[1] Paul T. Davis: A Description of the Hoskins Time Chart, *Journal of Cycle Research*, Vol. 5, No. 1, Jan., 1956.

A New Approach to Hot Tearing

shows that the hot tearing tendency exists in a narrow temperature range and is primarily effected by the heterogeneous freezing point of the metal.

Based on a Paper by C. F. Christopher

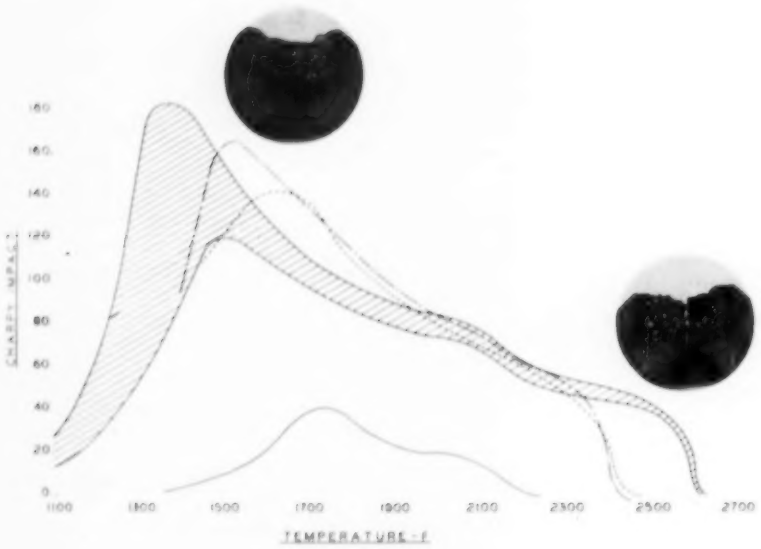


Fig. 1—Results of several hundred Charpy impact tests at temperatures from 1100° to 2700°F. Values falling within the cross-hatched areas were taken from eight heats of 0.30 pct C, but with varying amounts of Mn, Cr, Ni, and Mo. Insert, above 1600°C, shows steel just above austenitic transformation temperature; steel at its toughest point. Insert above 2600° shows the result of heating into the temperature range where grain boundary melting begins to occur; fracture is crystalline and brittle.

HOT tearing is only one of several physical defects originating from stresses during solidification and cooling. Piping, flow lines, shrinkage, cold cracks, and blow-ups are all similarly caused defects, and the physical nature of the metal at the time of stress-rupture determines the nature of the defect. Hot tearing, therefore, is a natural phenomena in all steels under similar time-temperature conditions. If, then, certain ranges of temperature produce different types of defects, it is important to know these temperatures.

The various defects are defined as follows:

a) *Piping*—occurs when an ingot or casting is highly stressed, but when the liquid metal is able to flow. The pipe, due to insufficient liquid metal, can be eliminated by further supply of liquid metal from a hot top;

b) *Flow Lines*—occur when liquid metal is present, but in lower temperature areas; caused by contraction stresses forcing liquid metal to flow through a partially frozen mass;

c) *Shrinkage*—occurs when contraction stresses act upon small pockets of liquid metal, which are trapped and unable to flow;

C. F. CHRISTOPHER is Research Director, Blaw-Knox Co., Continental Foundry & Machine Div., East Chicago, Ind. Paper is to be presented at Electric Furnace Steel Conference, Chicago, December 1956.

d) *Hot Tearing*—occurs when contraction stresses act upon steel, which still contains liquid metal present around the dendrites or austenitic grain boundaries;

e) *Cracks*—commonly referred to as cold cracks—occur below the austenitic transformation temperature.

With exception of cold cracks, these defects occur at temperatures where some liquid metal is still present. All steels are resistant to failures between the temperature where the last metal freezes, and the temperature where it transforms from austenite to ferrite and pearlite.

Testing Procedure

In order to define the temperature region where steel is susceptible to hot tearing, the author made use of the Charpy impact tests and microscopic examination. These demonstrated the temperatures where there was liquid metal in the grain boundaries, i.e. the brittle region.

Charpy bars were heated in a quartzite tube inserted in a carbon rod resistance furnace with a maximum temperature of 3000°F and an argon atmosphere to prevent oxidation. Temperature was controlled by thermocouples to ±10°. Samples were broken within 3 sec after removal from the furnace by ejecting the samples from their tubes into the Charpy impact machine.

Structural and inclusion studies required instant quenching to retain, as closely as possible, conditions prevailing at the temperatures in question. For this purpose, thin discs and drillings were placed in refractory boats and inserted into the argon atmosphere tube for heating. After desired temperature was attained, these samples were quenched in ice brine.

Charpy Tests Show Abrupt Brittleness-Ductility Change

In Fig. 1 curves are shown representing several hundred Charpy tests at temperatures from 1100° to 2700°F. These tests were broken at temperature under accurate control and argon atmosphere.

It can be seen that there is a marked change in toughness with steels tested at various temperature levels. At 1100°F, all tests were brittle and weak. In the 1300° to 1500°F range—austenitic and close to the transformation temperature—they became extremely tough and resistant to notch sensitivity. After the steels became austenitic—above the 1300° to 1500°F range—they were completely resistant to rupture at increasing temperatures until liquid appeared at the austenitic grain boundaries. Within this range of testing temperatures it can be seen that the values gradually decreased, due to softening of austenite with increasing temperature.

Every steel goes through an abrupt change from extreme ductility to extreme brittleness at some high temperature point. Since the last metal to freeze is highest in carbon and is located around the grain boundaries, this temperature point depends upon the melting point of the highest carbon metal and is greatly affected by the original carbon content of the steel.

A tremendous amount of high temperature impact testing has been done on a wide range of carbon steels, both acid and basic, and with various additions such as rare earths. The predominant factor in this sudden physical property change is carbon content of the metal, but nucleators, such as aluminum, are certain to have minor effects.

Solidification Defects Occur Before Lower Limit of Brittleness Band is Reached

Fig. 2 is a summary of impact test results superimposed upon a constitutional diagram. This diagram is not intended to be correct for any individual steel tested but is shown here to demonstrate the extent of embrittlement in steels of various carbon content.

There is a definite band of embrittlement which is unavoidably produced by the freezing phenomena. The lower limit of this band is the true solidus, and it has little to do with composition elements other than carbon. The width of this band increases with increasing carbon.

There is little doubt that all mechanical solidification defects occur before the steel has cooled to the lower limit of this brittleness band, i.e. before the steel is completely frozen. During the entire cooling cycle of a 0.30 pct C steel casting, all defects, with the exception of cold cracks, are formed before the steel cools to approximately 2530°F. It is important to know this simple fact, because it erases a lot of mysterious and false ideas concerning the location of hot tearing, and it may lead to a sounder approach.

Difficulty Lies with Uneven Cooling

The problem in eliminating hot tearing lies in the uneven cooling of castings, ingots, etc. Not only does one end of the casting cool faster than the other, but also the surface cools faster than the center. However, knowledge that hot tearing susceptibility is a natural phenomena, following definite temperature limits, does simplify the problem by diverting thinking from steel quality to one of simple mechanics. If susceptibility can not be eliminated, then means must be found in dissipating, equalizing, or minimizing excessive differential cooling stresses.

Applications to Practice

There is no question that better castings could be made at lower cost and at greater rate of production, if designer and producer would cooperate fully. It is not unreasonable to discuss certain changes with the customer regarding the increase in size of certain thin sections, adding permanent fillets to eliminate sharp corners, certain permanent paddings, etc.

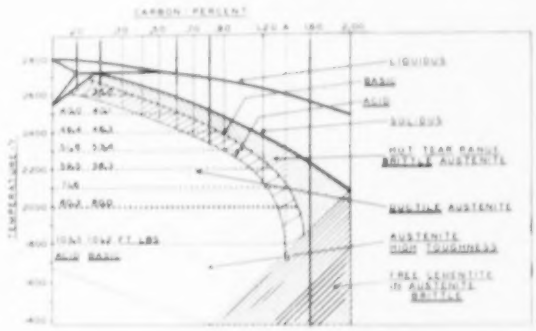


Fig. 2—Charpy impact test results for both acid and basic steels, superimposed on a constitutional diagram.

In planning any casting, regardless of its degree of susceptibility to hot tearing, the first consideration must be for soundness. In this manner the location of the heads, their number and size, and other considerations are determined. Furthermore, the overall design and shape is studied in order to position the casting in the mold for natural directional solidification.

After adequate feeding, stress relief and distribution by proper gating, chilling, and heading arrangement are most important. It must be decided whether to eliminate a tendency to crack in a certain location by chilling that area, or by removing the stress condition somewhere else.

The ultimate in planning is the arrangement of heads, gates, and chills in such a manner as to allow the casting to be fed properly, and at the same time produce maximum temperature distribution until the entire piece is below the hot-tear range. Chilling may help by pulling certain areas below the hot-tear range early in the cooling.

Lower Pouring Temperatures Lessen Incidence of Hot Tearing

While the author believes that the carbon level alone controls the hot tear susceptibility, there is a great difference between *susceptibility* and *incidence of hot tearing*. A high chrome steel and a high manganese steel of the same carbon content have the same hot-tear susceptibility, but their incidence of hot tearing is far different. The term susceptibility refers to the temperature range in which tearing may occur, but incidence takes into account the

time at which stress is applied. If steel is stressed within the susceptibility range, it will tear. Incidence, then, is the major problem.

Chemical composition, other than carbon, has a great deal to do with fluidity, setting, and feeding characteristics. Highly fluid compositions can be poured at lower temperatures, allowing critical areas of a casting to drop below the hot-tear range before major stresses appear. However, less fluid compositions must be poured hotter, and their quicker setting characteristics cause stresses to occur at higher temperatures. Although there is no pouring temperature which will cure a bad stress condition in intricate castings, a low pouring temperature makes it easier to counteract the effect of stresses. For a given casting, incidence of hot tearing decreases with decreasing pouring temperature.

It has been proven that tearing occurs within a very short time after the steel enters the mold; in fact many tears occur before pouring is completed. Stresses produced during the initial part of skin freezing are quite large, and the steel subjected to these stresses is quite weak. It is, therefore, impossible to produce a sand that would readily yield in preference to the steel at this early period and still have tenacity to produce clean castings.

Collapsibility does not enter the picture in many cases. Castings that have parts and members which are not free to move may tear, because every member is tied to and pulls against another. This type of casting cannot greatly be improved through sand or core conditions. It must be headed, gated, and chilled for even temperature distribution, and poured at a temperature which allows all critical areas to drop below the hot tear range quickly and evenly.

Gating, Heading, and Chilling Methods Important in Preventing Hot Tearing

A gate is a means of filling a mold with liquid steel, and it can cause hot tearing if not done correctly. Gating is the major means of offsetting the ill effects of the temperature differential of heavy sections and heads. If hot tearing is ever eliminated, gating technique will play the most important role.

A head is a receptacle for feeding castings, and it too may be harmful as well as beneficial to hot tearing. Generally speaking, heading increases the susceptibility to hot tear, because it produces hot spots, and heads are usually placed over the heavier sections of a casting, thereby increasing the temperature differential. Heads should be held to a minimum size, with more small heads being used in preference to a few heads of large volume.

A chill is a means of strengthening certain areas of a casting and accentuating directional freezing. This, like heading and gating, must be used with care. Discriminate use of chills gives temperature control often impossible through heading and gating alone. Generally, chills should be placed so as to bring about directional solidification and lower the temperature in areas of high stress concentration.

Key to Hot Tear Problem is:

Full Knowledge of Physcial Properties of Steel at High Temperatures, and Adjustment of Heading, Gating, and Chilling, and Metal Temperatures to Suit these Physical Properties.

Temperature differential is necessary to feed castings directionally, but no casting can be over-stressed during this period of feeding until all sections of the casting have reached temperatures approximately 100° under the freezing point.

The key to hot tearing can best be exemplified by the casting of steel rolls. Such rolls, being massive, require accelerated cooling over their entire body and are thus made by directional solidification. Every section is cooled, but some sections of the surface require accelerated cooling, which produces an overall directional freezing and a time-temperature cooling at stress concentrating areas.

This directional temperature condition is brought about with chills, the size and volume of which may be tremendous in the case of steel rolls. For instance, a 30-ton roll may require approximately 20 tons of chills to bring about solidity. The chills must be placed so that stress concentrations are not de-

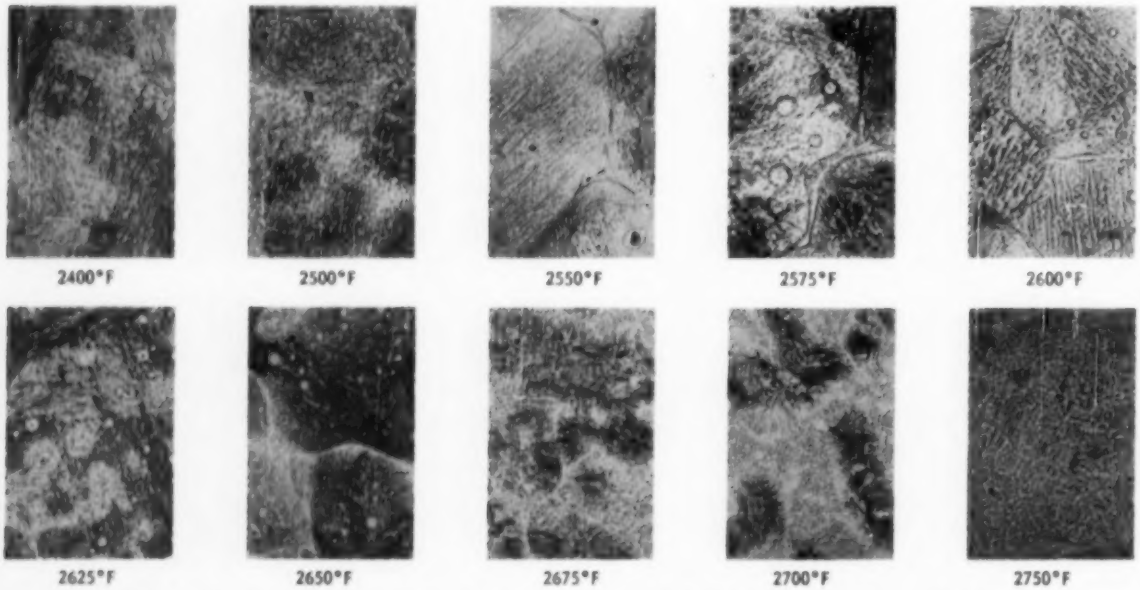
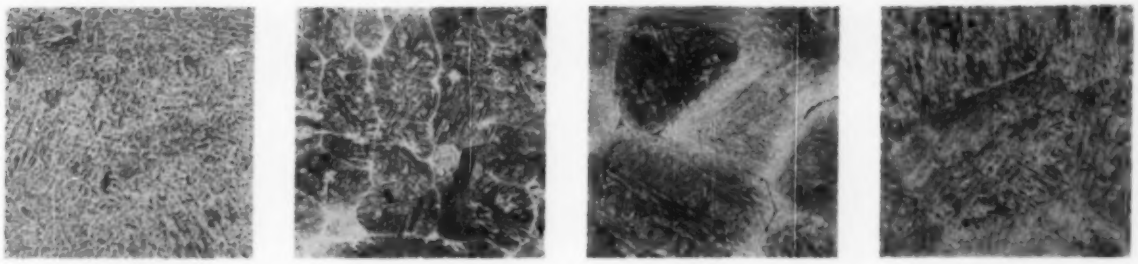


Fig. 3—High-chrome acid steel, 0.29 pct C, reheated to the temperatures indicated, held 20 min, and quenched into ice brine. Nital etch, 50X.



2750°F 2700°F 2600°F 2500°F

Fig. 4—High chrome acid steel, 0.29 pct C. Original structure heated to 2850°F, cooled to temperatures indicated, held 10 min, and quenched into ice brine. Nital etch, 50X.

veloped while the skin of the steel is in the hot-tear temperature range. For instance, stress areas on intricate passes are chilled quickly and heavily to bring these areas down below the hot-tear zone before overall contraction takes place.

The same fundamental principles are involved in making an intricate casting. Not only are there more concentrated stress areas, but the thinner sections naturally cool faster than heavy sections. This condition must be counteracted by manipulating the temperature through heading, gating, and chilling. These castings require chills in the stress concentration areas, but other parts of the casting must be decelerated in cooling until the stress areas are below the hot-tear range.

No steel will stand stresses until the hot-tear range is passed. The tools used to avoid such stresses are heading, gating, chilling, and pouring temperatures.

Microscopic Study of Structures Near Hot-Tear Range

The photomicrographs in Fig. 3 represent the structural conditions, which take place at high temperatures in the range of solidification. These structures were produced by re-heating small samples of the original cast structure to progressive temperatures, holding 20 min at temperature, and quenching in ice brine.

Although several types of steel have been studied in this manner, a 0.29 pct C, high chromium, silicon-killed acid steel is shown throughout. Original physical studies on this particular steel determined the hot-tear range to be between 2500° and 2600°F.

The first photomicrograph shows the structure 100°F or more below the hot-tear range. The austenitic grains are large, and show evidence of coring. There is no evidence of melting or grain disintegration at this temperature. But as the temperature is raised, the austenitic grains increase in size with the same evidence of coring. At temperatures immediately under the hot-tear range, there is no evidence of grain boundary weakness. Impact tests at 2500°F show no evidence of brittleness. At 2550°F, the steel begins to show the first signs of disintegration. The austenitic grain boundaries are becoming more pronounced, and, within the grains, small areas are beginning to melt. Impact testing at this temperature begins to show marked brittleness.

When heating from 2550°F up to the melting point, large austenitic grains break up into smaller ones until the grains gradually disappear into liquid. The photomicrographs show clearly how the grain boundaries become more prominent and how melting takes place within the grains. The impact value is zero at such elevated temperatures.

During the freezing cycle, every steel sets up a structural and chemical heterogeneity which remains intact regardless of subsequent treatment. Steel that has been homogenized or quenched and tempered gives the same hot-tear temperature range when reheated to these high temperatures as the same steel in the as cast condition. From these findings it is believed that research on microstructure and Charpy impacts carried out in a heating cycle gives the true hot-tearing characteristics and temperature ranges of embrittlement.

Research work on hot tearing, conducted by other investigators, has been done during the freezing cycle, but the author does not entirely subscribe to this type of approach due to the inaccuracy which may be present in detecting temperatures and physical changes.

Extremely accurate temperature and impact measurements can be made by heating impact specimens to the various required temperatures. Furthermore, accurate photomicrographs can be made at various temperatures by quenching small samples in brine. The microscopic structures on heating clearly show the change from ductility to brittleness and agree with change detected by impact testing.

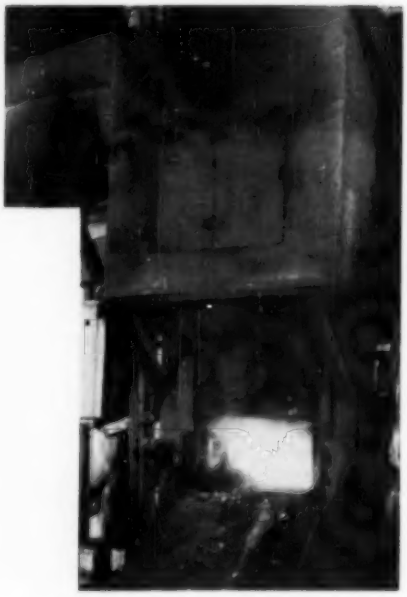
This report would not be complete, however, unless there was some degree of proof that there was an agreement between this investigation, conducted on a heating cycle, and the actual conditions occurring in the original solidification of the casting.

The best method of studying the cooling cycle is by a study of cooling microstructures, which can be compared with microstructures and physical properties attained on heating. If cooling micrographic conditions agree with heating structures and properties, then the hot-tear ranges can easily be determined by reheating methods.

Shown in Fig. 4 are microstructures of a 0.30 pct C steel heated to 2850°F, cooled to the indicated temperatures, and quenched in ice brine. The structure at 2750°F represents the steel that is liquid or just beginning to freeze. At 2700°F the austenitic grains are small, and there is distinct grain boundary weakness in evidence. At 2600°F the austenitic grains have grown in size, but weakness still exists around the boundaries. Impact tests at this temperature were practically zero and showed a brittle grain boundary fracture. At 2500°F the steel has completely frozen and shows large austenitic grains. Impacts at this temperature show complete ductility.

Thus, it can be seen that the impacts and microstructures on heating agree with the microstructure on cooling as far as brittleness detection is concerned. The author, therefore, feels that the experimental technique used is justified.

Based on an Article by
C. W. Finkl



Small Melting Shop Dust and Fume Control

JUST a few years ago, effective smoke collection from an electric furnace was next to impossible. At the A. Finkl & Sons shop; heavy dust particles covered the equipment, and on humid days, the pall of smoke in the shop was such as to practically eliminate visibility between floor and crane cab. Dust was being discharged over the neighborhood, and it was felt that atmosphere in the shop was neither safe nor healthy. Something had to be done! In the intervening period, much progress has been made. Although the atmosphere in the shop isn't always sparkling clear, it is felt that dust and fume are under good control, and the previous hazards and nuisances have been eliminated.

Finkl & Sons melt shop is equipped with two 20-ton Moore *Lectromelt* furnaces. Fume was originally controlled with seven 24,000 cfm roof ventilators, operating between two corrugated sheet metal curtains, 75 ft apart, and extending from the bottom of the truss to the top of the roof. These exhaust fans consumed a total of only 14 hp and did a reasonably good job of exhausting fume during the summer months when using clean scrap and single slag heats. However, during the cold weather, when the windows and doors at the base of the building were closed, the roof ventilators would side-track air around the curtains from the overhead louvers and not from the furnaces. When all-heavy scrap charges were no longer available, and the plant changed over to all-double slag heats, the smoke condition became serious. The exhaust fans seemed useless, and it became evident that means must be provided to bring heated air in at approximately floor line to carry the smoke up to the roof fans.

The first step was to install eight 25,000 cfm fresh air heaters, providing 200,000 cfm of 60°F fresh air some 6 ft above floor line. These heaters can condense close to 10,000 lb of waste steam per hr and return it to the boilers for make-up. This paid for the additional 80 hp fan to run the heaters. Close to the floor line, heated air helped fine particles of dust rise to the exhaust fans and louvers, but heavier particles would still precipitate on the equipment,

C. W. FINKL is Plant Engineer at A. Finkl & Sons Co., Chicago.
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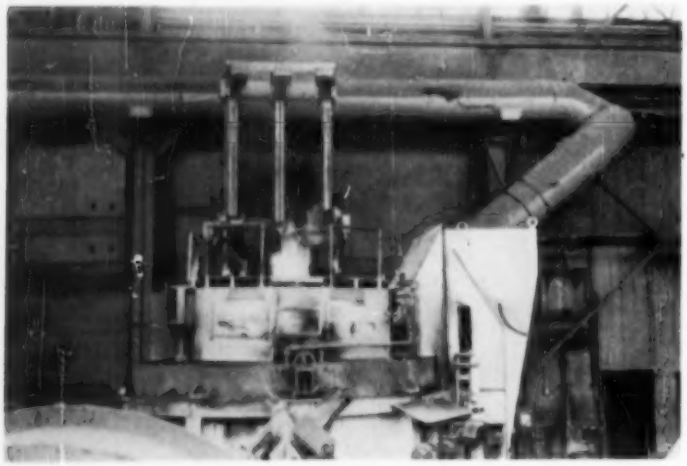
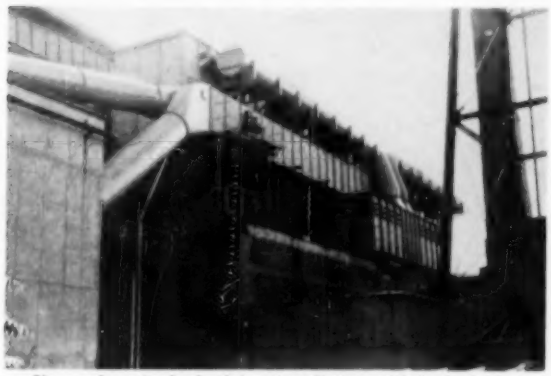


One of the two *Lectromelt* furnaces in the A. Finkl & Sons shop is shown at left, with the hoods in operation. Between 3 and 6 lb of dust per ton are collected, depending on the cleanliness of the scrap. Previous to installation of the hoods, much of this fume due to its extremely fine nature, would have been hanging in the air.

and visibility was poor on humid days. Hoods for the furnaces and dust collectors were the next move.

Selection of Equipment

Hoods were selected from the catalogue of American Air Filter of Louisville, but choice of a suitable dust collector appeared to be a much greater problem. Rotary collectors, electronic precipitators, wet collectors, and bag type collectors were considered. Due to the extremely small particle size, large volumes, and capital investment required, the bag type collector manufactured by the Wheelabrator Corp. of Mishawaka, Ind. was selected. No doubt there are any number of suppliers for this type of equipment, but their dust collector fitted nicely on the plant's fire-brick storage building.



Shown above is the baghouse installation, with both the intake and exhaust manifolds clearly visible.

Description of Equipment

The hood is in three sections: the first section over the charging door contains a sliding companion flange, plenum chamber, and distribution damper. The center section has three non-magnetic stainless steel flappers around the electrodes to facilitate maintenance of the cooler rings, and help reduce the hysteresis losses in the hood. The front section has a slot to collect whatever fume comes from around the spout. All three sections are supported on roof supporting arms and the 13-ft 6-in. roof ring. Each complete hood requires 31,500 cfm at 4 in. water gage suction.

Two separate dust collectors of six bag houses each are assembled into one continuous unit 100-ft long and mounted on top of an adjacent building. Only five of the six bag houses are in operation at the same time, with one of the bag houses being valved off for shaking into its 60° hopper. Rotation from one bag house to another for shaking is automatic, and duration of shut down and bag shaking is adjustable. The bag ratio is 2.92 cfm per sq ft with one bag house off the line for shaking, and 2.44 cfm per sq ft of bag area with all units in operation. Each furnace has its own exhaust system, but the two 60 hp exhaust fans can be cross-connected if one should fail. These fans are on the clean air side, permitting the use of backward curved blades instead of the long-shavings type, which would be necessary if fans were on the dusty or inlet side of the bag houses. This method of installation is a little more expensive, due to additional manifolding, but has the following advantages: 1) more efficient non-overloading type fan; 2) easier starting, lighter fan wheel; 3) impeller stays clean and lasts longer; 4) less vibration for overhead installations; 5) bag houses under suction instead of pressure won't leak dust; and 6) effluent can be discharged back into shop on cold days to save the waste heat.

Fume temperature into the the bag houses is limited by a motor-operated, 15 in. butterfly valve that vents fresh, cool air into the system, if the duct temperature should reach 275°F. If this should prove insufficient or fail, a 12x12 in., gravity operated, drop-out damper in the shop will open at 300°F. Each hopper has a rotary valve, discharging into a common conveyor so the hoppers can be emptied during operation.

Installation

Regardless of the kind of hoods used, you will find that they don't fit the measurements; so don't try to install them between heats. Sometimes a week-end may even be too short! It depends on how accurate measurements are and how much the furnace has warped and distorted between the time of measurement and assembly.

Chicago Blow Pipe designed and erected the ductwork according to our specifications, which accommodated both the hood and dust collector requirements. The ductwork, as usual when properly installed, proved to be maintenance free.

Results

Probably the most interesting, if not the most important items, are capital costs and operating expenses. The first part can be hit on the nose as follows:

Structurals	$ 891.70
Electrical equipment not supplied	2701.53
Dust collector	52770.00
Edison-excess facilities	946.00
Iron & sheet metal workers	10609.40
Leads & Northrup recorder	1158.05
American Air Filter hoods	11556.68
Painting	2687.00
Chicago Blow Pipe ductwork	17499.00
Own labor	6374.32
Odds and ends	465.78
Total	$107,659.46

By taking an accelerated five year depreciation and adding an estimated two year bag life, power consumption, and maintenance, then dust collection will probably come close to a surprising $1.00 per ton. However, the effect on operation is not so discouraging, and it was found that hoods and dust collectors are not as hard to live with as might be expected. The dust collectors started operating on Oct. 18, 1954. For a 13 week period prior to that date, kwh per ton averaged 524, and for a similar period afterwards, the average was 520 kwh. A similar negligible comparison was observed in electrode consumption, although a higher electrode column is now carried, so the electrode clamps will clear the additional hood height without changing operations appreciably. Likewise, refractory life of the roofs has remained relatively unchanged, although it takes longer to change a roof with a hood installed. Whenever it is possible, roofs are changed on week-ends when the shop is down. The cooler rings take much longer to remove than before and are difficult to change with the hood in the way.

Between 3 and 6 lbs of dust per ton are collected, depending on the cleanliness of scrap and operating

conditions. The dust is one of the messiest waste materials ever handled—it just seems to get all over everything! To minimize this, it is collected from the screw conveyer into paper bags, each containing about 80 lb of dust. Even this was a filthy operation until a little bagging booth was set up and kept under suction from the dust collector manifold. At first, bagged dust was recharged to reclaim some of the alloys and save paying the scavenger to haul it away, but the pounds of dust per ton kept going up until the practice was discontinued. Dust analysis is shown in Table I.

Probably the greatest unknown factor confronting the plant engineer in installing a dust collector is the temperature of the effluent coming from the hoods. Results of more than a year's operation indicate that peak temperatures last only a few minutes and usually occur during a *blow* or a *cave-in*. Peaks of 300°F have been recorded, but generally they run in the neighborhood of 275°F. The average maximum temperature per heat is around 200°F, and the overall average runs close to 130°F, which is a safe figure for the Orlon bags being used.

Bag life should exceed the guaranteed figure of two years. Only a half dozen bags have been replaced so far, and they either tore from not being properly anchored, or had a small hole burned through. The remainder of the bags are still soft and pliable, dark brown in color, and seemingly covered with an oily film. They look as if they should last for a few more years. Bags are inspected weekly to see that they are properly anchored and that there are no leaks. Pressures across each bag house are checked daily to make sure that bags are shaking clean and that dampers and program control of the shake-down periods is functioning properly.

Table I. Electric Furnace Dust Analysis, Pct

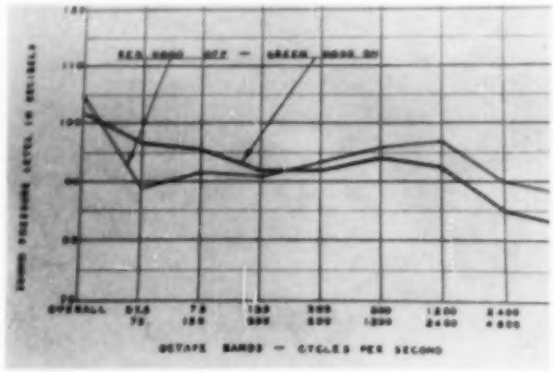
FeO	4.2	MgO	7.0
Fe_2O_3	35.04	C	2.3
CaO	14.9	Cr_2O_3	1.2
Al_2O_3	12.9	NiO	0.3
SiO_2	6.8	P_2O_5	0.1
MnO	12.1	S	0.26

Plus traces of molybdenum and vanadium.

Hood life has been rather discouraging, and hoods have been rebuilt about every six months. If the hoods warp too badly, especially around the electrodes, much of the fume escapes, and the hoods become inefficient. Most of the structural supporting members have been taken out from under the top plate and replaced with 30 to 40 lb per yd rails above the top plate. Cast heat-resisting, alloy flappers to go around the electrodes also have been ordered. This combination should appreciably increase hood life. The construction is no more expensive, as relaying rails can be used, and the cast flappers are cheaper than sawing flappers out of stainless steel plate. It costs between $800 and $900 to rebuild a hood.

Addition of hoods has had no effect on the oxidation of the reducing slag, but to check the effect of the hoods under suction, draft readings were taken at the slag line. Furnace pressure at this point averages −0.02 in. water gage, with or without the exhaust fans in operation.

With all shops becoming noise conscious, and having the necessary equipment for measuring noise in the forge shop, it was decided to check the electric furnaces for noise, with and without hoods. The results were gratifying, as the hoods reduce the furnace noise output by about 5 db in the critical octave band around 4000 cps. They also reduce the overall readings, but they must work like a sounding board, since the noise ouput in the lower, less harmful frequencies is accentuated. Audiometer tests are run on all employees at least once a year, and so far, none have shown any hearing loss as a result of working in the melt shop. Therefore, noise must be below the critical level.



Plot of the noise level in the melt shop, showing how the hoods accentuate the lower frequencies, while diminishing the more irritating high frequencies.

Effectiveness of Installation

The question of "how much of the dust do we collect?" is at best a guess, since there is no way of measuring how much escapes. Visually, under normal operating conditions, and comparing one furnace with the hood on, while the other is operating with no hood, it is estimated that between 80 and 90 pct of the dust is collected.

The system is satisfactory for what it was intended. The shop is now a much cleaner and safer place to work. The crane operator doesn't lose sight of the floor; however, the small percentage of smoke that does escape hangs around the shop on humid days and leaves something to be desired.

The dust collector does an excellent job of extracting dust. Piping the effluent into the shop didn't prove practical, since during a carbon block, the amount of carbon monoxide in the shop became too high.

During the operating periods of the furnaces, the shop is fairly free from smoke; however, during tapping and teaming the smoke in the shop again becomes a problem. A lateral type hood has been used to try to catch some of the smoke emitted during tapping, and about half of it is collected. The smoke is piped into the dust collector of the furnace that is tilted, since its hood is inoperative during tapping anyhow. This system was improved by adding an axial flow blower in the opposite side of the pit. It discharged into a long slot, blowing 6400 cfm across the ladle and above the tapping stream, to force the smoke into the lateral hood. This addition proved to be effective, but its use was discontinued until the lab could give definite proof that the tap stream was not being oxidized.

Nothing has been done, as yet, to collect the smoke from teaming, as it seems impossible—but, a few years ago, it seemed impossible to collect the smoke effectively from electric furnaces.

Great Falls Billet Plant

A description is given of the construction and operation of a billet plant designed and built at the Anaconda Co. plant in Great Falls, Montana. The plant produces 3 in. diam P-Cu billets with a high phosphorous content from cathode copper.

by Roy H. Miller and L. J. Ingvalson

IN 1948, as part of a program to expand the copper tube mill facilities of the American Brass Co. plant at Kenosha, Wisconsin, plans were formulated to convert the 100 ton capacity anode casting furnace at the Great Falls, Montana plant of the Anaconda Co. to the production of 3 in. phosphorized billets. The furnace was rebuilt completely and construction was started on an addition to the building.

Members of the Great Falls staff visited various billet casting plants to draw upon the experience of other producers of this type of casting. Many features of other plants were incorporated into the Great Falls plant but, in addition, many new designs were made and perfected to make the plant the most advanced of its type.

Construction was begun in 1949, with the intention of having the plant in production in the early part of 1951. In January 1951, as the plant was being rushed to completion, the government placed restrictions on the production of copper tubing. As a result, work was halted and the plant lay idle for two years. Interest was reactivated in May 1953 with the lifting of restrictions on copper. Plans were laid to go into production in July and the first charge was taken out July 1, 1953.

Basically the plant is designed to produce from cathode copper a 3 in. diam billet, 50 in. long, weighing 110 lb, and containing 0.013 to 0.036 pct P, at a rate of 150,000 lb per operating day. These billets are to be pierced and drawn into tubing.

Furnace

The furnace is a 100 ton capacity reverberatory type, gas fired furnace; 21 ft long and 9 ft wide. Gas is introduced to the furnace through two 38 hole Mettler gas burners. These burners are of chrome nickel alloy with four jets per hole. The furnace is charged with cathodes from the Electrolytic Copper Refinery plus return scrap from the casting operation by means of a Wellman Seaver Morgan Co. 7,000 lb capacity charging machine. The charge crane has a 20 ft boom and fork peel provided with an air ram to push material off the peel. The machine travels on overhead tracks and can be moved in any direction. The boom can be raised and lowered and swung through an arc of 180°. With well stacked units of 6,000 lb, an experienced operator can put the first charge into the furnace in 40 min.

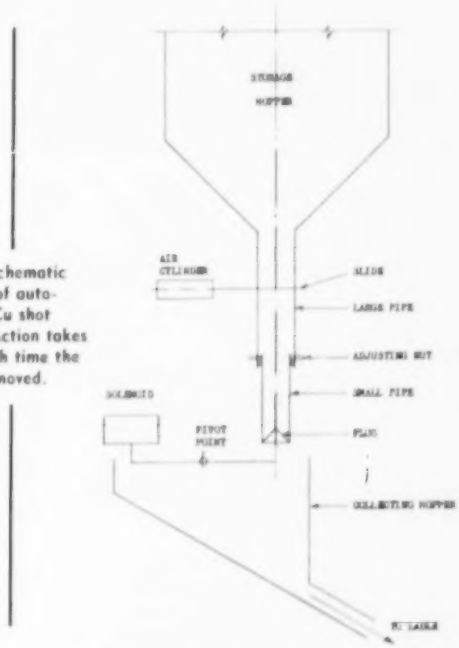


Fig. 1—Schematic diagram of automatic P-Cu shot feeder. Action takes place each time the wheel is moved.

After charging, the steel framed silica brick charge door is put in place and sealed with clay. After melting and skimming off the slag, the copper is blown until an oxygen content of 0.40 pct is reached. The metal is then heated to 2180°F, covered with coke, and poled. Poling is continued until a 3 in. diam test billet, 8 in. long, shows a flat set. The oxygen content is usually 0.030 pct at this time. At the end of poling, a temperature of 2160° to 2180°F is desired.

In the side of the furnace opposite the charging door is the taphole slot, extending 36 in. upward from the bottom of the furnace. It is 4½ in. wide at the outside face and widens to 9 in. at the inside face of the furnace. It is filled with a wet mixture of sand, fireclay, and crushed coal. Flow of metal

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The Transactions papers appearing in the JOURNAL OF METALS *during 1956 will subsequently appear in AIME Transactions Volume* 206, *and may be permanently referenced to that volume.*

Fig. 2—General view of casting wheel shows the 16 two-pocket, water-cooled molds, general piping arrangement and, in the background, the funnel and pouring ladle. Hood over ladle is part of exhaust system for carrying away dust and fumes.

from the furnace is controlled by successively cutting small portions of the taphole clay.

The location of the taphole, charging door, burners, and charging machine caused limitations in the space available for the casting machine, presenting some problems in design, all of which were eventually overcome.

Casting Machine

Copper from the furnace flows down an 8 ft launder to a 1,000 lb capacity ladle. The ladle is controlled by a hydraulic system made up of two Vickers pumps driven by two 2 horsepower ac motors which maintain 400 lb of pressure. The ladle is raised by a 5½ in. hydraulic cylinder controlled by a Servo valve.

The ladle lips are designed to pour simultaneously into two funnels, which deliver copper to the two pockets of the mold.

Funnels—Originally, the funnels were hand made of a mixture of sharp sand, cement, and a little fire clay shaped in a steel shell. The bells of these funnels were 4¼ in. sq, with a throat 2¾ in. long and ¾ in. in diam. The life of a funnel was less than one day. Various types of high temperature cements were tried, without much success.

Present funnels are purchased from Harbison-Walker Refractories Co., and are made of the same material used for the production of Duro brick. These funnels have been found to be far superior in quality and give a much longer life than any that could be made locally. One funnel usually lasts from two to three days.

The Duro funnels now in use have a rectangular bell 6½ in. long by 4 in. wide, with a 11/16 in. sq throat 4⅝ in. long.

Phosphorous is added to the ladle automatically after each pour in the form of a 1/16 in. diam shot, 85 pct Cu and 15 pct P, in sufficient quantity to deoxidize the copper and leave an average phosphorous content of 0.025 pct.

Phosphorous Feeder—The operation of the automatic dispenser, see Fig. 1, is as follows:

A storage hopper large enough to hold 1,000 lb of shot, slightly more than a day's supply, is mounted above and to one side of the pouring ladle. A short length of 1 in. pipe extends down from the conical-shaped bottom. A slide similar to a gate valve is located at a predetermined distance from the lower end of the pipe, and is operated by a 1 in. air cylinder. At the bottom end of the pipe is a plug which is operated by a solenoid.

Normally the slide is open and the plug closed, allowing the pipe to fill with shot. Each time the

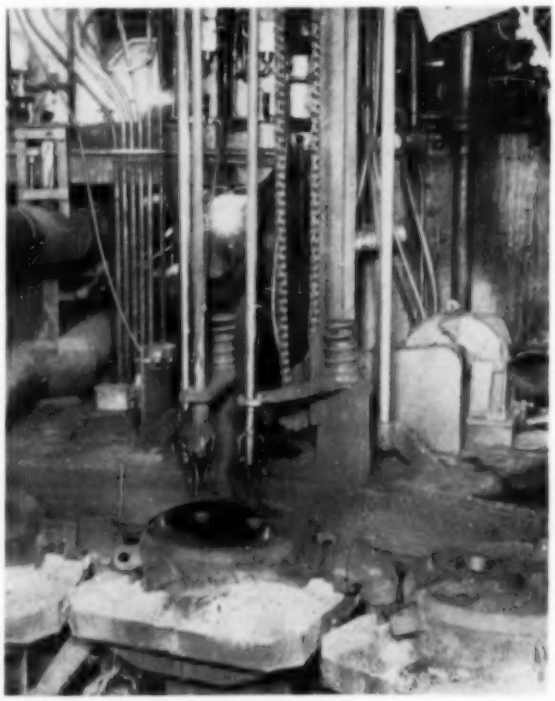

Fig. 3—Automatic painting machine sprays a light coat of a graphite, bone black oil mixture on each mold. Spray heads are lowered into the molds by gravity and are raised by an electric motor and chain drive mechanism. A similar machine is used for brushing the molds, except that brushes operated by Elliot air motors are substituted for the spray heads.

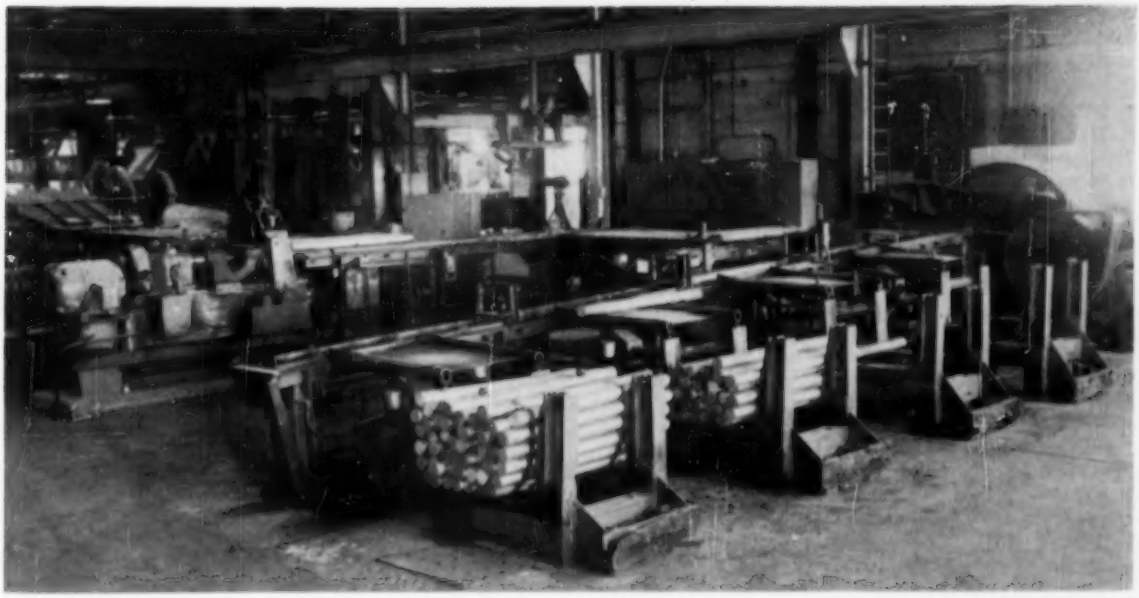

Fig. 4—General view of inspection and sorting conveyor. The cropping machine is at the extreme right of the sorting conveyor. A pile of 51 cropped billets has been banded and is ready for loading onto an industrial railroad car by a 6,000 lb capacity fork-lift truck. Additional billets have been diverted to the second bin while this action takes place.

wheel moves, the slide closes and the plug opens, allowing the measured amount of shot to drop into the collecting hopper and then through a pipe to the pouring ladle. Approximately 280 g of shot are added for each pour of two 135 lb billets.

The copper in the ladle is kept covered with charcoal to prevent oxidation.

The ladle operator is stationed above and to one side of the pouring ladle and can control the delivery of copper to the mold by tilting the ladle. Pouring time for one mold (two billets) is 15 to 20 sec. The billets are not *gated*. Casting rate is approximately 40,000 lb gross production per hr.

The molds consist of two steel tubes 3⅛ in. ID with ¾ in. walls 62 in. long encased in a steel jacket 12 in. in diam and spaced 5¾ in. center to center. Both top and bottom of the jacket are welded to the tubes and a slip joint is provided to allow for expansion of the tubes. Water at 130°F is circulated through the molds by a 1000 gpm capacity centrifugal pump. Prior to casting, the water is heated with steam to bring it to the proper temperature. During casting, the temperature is controlled automatically by a thermostat which adds cold water to the supply tank as needed.

There are 16 molds on a 16 ft diam casting wheel driven by a 10 horsepower ac motor by means of an outside ring gear and pinion. Each mold rests on a 12x6x3 in. copper base plate which is suspended by a steel framework from the spokes of the casting wheel and is hinged to open and allow the billets to drop out, Fig. 2.

The ladle operator moves the wheel after each pouring by a push button control and the wheel stops automatically at the next pouring spot.

At a point 90° from the pouring spot, the base plates are partially opened. At 180° from the pouring spot, the base plates open and allow the billets to drop into a water bosh. Then, at the next spot, the molds are brushed to remove any loose carbon; as the mold passes the following spot, the base plates are closed. In closing, the molds are raised about ½ in. This insures a tight seal between base plate and mold. After closing, the mold is painted with a mixture of bone black and graphite in light fuel oil and is ready for the next pouring.

Each time the operator presses the button to move the wheel, the following automatic operations take place.

1) A feeder drops a measured amount of 15 pct P-Cu alloy shot into the pouring ladle.

2) As the wheel moves, a base plate is partially opened at a point four spots from the pouring spot.

3) A base plate is closed after passing the brushing spot.

When the wheel stops for the next pour, the following automatic operations take place and must be completed before the wheel can be moved again.

1) The base plate of the mold 180° from the pouring spot is opened, allowing the billets to drop into a water bosh. They fall into a *basket* and the shock of the billets hitting two striking plates closes the contact in two mercury switches. Through a series of relays and solenoid valves, an air cylinder moves the basket to a horizontal position and rolls the billets onto a conveyor, which carries the billets out of the water and onto the inspection table.

2) The mold just past the dumping spot is brushed to remove loose carbon by rotating wire brushes driven by Elliot air motors. The brushes are suspended directly over the mold. When the wheel stops, the brushes are allowed to drop into the molds and are then driven to the bottom by an electric motor, through a sprocket and chain drive. When the brushes reach the bottom of the mold, the motor reverses and raises the brushes out of the mold. To prevent possible damage to the machine, the system is interlocked electrically, so that the

wheel cannot turn until the brushes are out of the mold tube.

3) The mold three spots past the brushing spot is painted with the bone black, graphite, and oil mixture. This is done automatically by a machine similar to the brushing machine, Fig. 3, except that instead of brushes and air motors, the ends of the pipes which enter the mold tubes are equipped with a spray-head, which atomizes the paint mixture by means of low pressure air and sprays a thin coating of paint on the mold. The painting is done on the upward stroke only.

Inspecting, Shearing, Sorting, and Loading

The billets roll past an inspector, who checks each one for surface defects. Any billet which would not be acceptable to the tube mill is rejected. After inspection, the billets roll on down a table to a cupping machine. This machine will drill a 1 in. diam, 1 in. deep hole in the bottom end of each billet in 3 sec.

The billets pass on to a shearing machine. As cast, the billet is about 60 in. long, but has a 10 in. deep shrink-hole in the top. This must be cut off before the billet is acceptable to the tube mills. The shearing machine is a Hill Acme Alligator Shear driven by a 7.5 horsepower ac motor, and making 30 strokes per min. The operator feeds the billet into the machine to a predetermined mark. If the cut billet shows no sign of shrink-hole, it is sent down the sorting table. If a shrink-hole is visible, the billet is cut again to a shorter length. If this does not eliminate the shrink-hole, the billet is scrapped.

After shearing, the billets are sent down an inclined roll conveyor and are automatically sorted according to size, counted, and dumped into cradles. Three flag switches are mounted beneath the rolls at each dumping station. The switches at the first dumping station are arranged and wired to dump any billet less than 43 in. long. This is done by having two switches 43 in. apart, with a third switch in-between. A billet longer than 43 in. will actuate all three switches, which simultaneously allow it to pass this station and continue along the roll table. A billet shorter than 43 in. will actuate only two switches and will be dumped into the cradle. These billets are scrapped as being too light.

Billets which pass the first dumping station continue on to the second dumping station, where any billet between 43 in. and 47 in. in length is dumped into a cradle utilizing the same principle as the first station. These billets are classed as 100 lb billets.

Billets longer than 47 in. continue on to the third and fourth dumping stations, and are classed as 110 lb billets. Maximum length of a billet is 52 in.

The billets are counted automatically as they are dumped. When 51 billets have been delivered to a cradle, no more can enter until it has been emptied, see Fig. 4. A truck operator bands the 51 billets, removes the bundle from the cradle with a 6,000 lb capacity fork-lift truck, and places it on an industrial car. The billets are then trammed to a loading platform, where they are loaded into box cars for shipment to various American Brass Co. plants.

Discussion of this paper sent (2 copies) to AIME by Feb. 1, 1957 will appear in AIME *Transactions* Vol. 209, 1957, and in JOURNAL OF METALS, October 1957.

Low Manganese Steels For Nuclear Applications

When the radioactive isotope of manganese is not wanted, low manganese steels of 0.10 to 0.15 pct Mn have been made by the basic open hearth process and rolled into plate, bars, and seamless tubing. The low manganese steels are interchangeable with standard grades of carbon steels for many uses. They are superior to standard grades of carbon steels in terms of freedom from strain aging, improved high temperature strength and ductility, and absence of certain disadvantageous nuclear or chemical properties.

by H. F. Beeghly

UNTIL recently the only criteria by which steels were judged were their cost and their mechanical, chemical, and physical properties. The user was concerned with such properties as corrosion resistance, tensile strength, response to thermal treatment, hardness, ductility, and, to a growing extent in recent years, with behavior at high temperature. As plans were made to build power reactors, a new set of properties became important—the nuclear characteristics, which had to be considered by the designer and engineer in building his plant.

The nuclear engineer developed methods for the rare and new metals and produced them in high purity, often at great expense. The pure metals then provided the raw materials for tailor-made alloys. For more common structural metals, such as steel, the nuclear industry depended on commercially available materials. Generally, the quantities required were small and specifications were rigid. It is not surprising, therefore, that difficulty was frequently encountered in procuring structural mate-

H. F. BEEGHLY, Research Engineer, Jones & Laughlin Steel Corp., is on leave to Westinghouse Electric Corp., Bettis AEC Plant, Pittsburgh.

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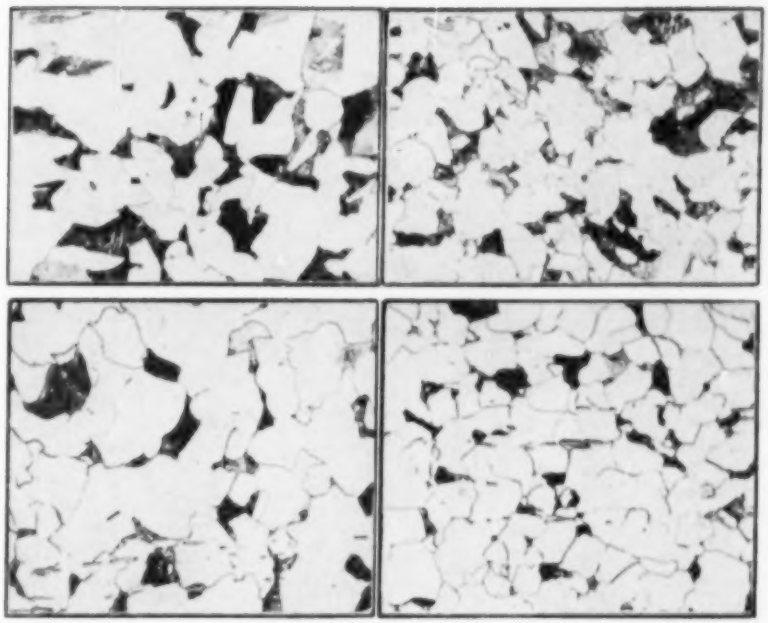


Fig. 1—Microstructures of low manganese steels. Upper left, standard A212 as rolled; upper right, standard A212 normalized; lower left, RH-1031 as rolled; lower right, RH-1031 normalized. Etchant 3 pct Nital. Magnification X500, reduced approximately 15 pct for reproduction.

rials, and less than the ideal material was obtained sometimes for a given application. Today, structural materials constitute probably the most serious limitation to construction of nuclear power plants of high efficiency at low cost.

In designing a steel for nuclear applications, what properties need be taken into consideration? First, structural integrity is even more necessary here than in most other applications. Second, corrosion resistance is very important. The corrosion media include such diverse materials as water and liquid metals. Third, the nuclear characteristics must be right. Good thermal conductivity and resistance to radiation damage are also important. A more detailed treatment of the requirements for nuclear structural materials may be found in publications such as those of Stephenson[10] and of Hausner and Roboff.[8]

Table I shows the elements common in commercial steels, arranged in order of decreasing cross sections for thermal neutrons. Assuming that a large cross section is undesirable, manganese is the major offender common to all grades and types of steels, amounts used being of the order of from 0.25 pct in low carbon steels to 2.5 pct in the 18-8 type alloy steels. If interest is confined to carbon steels, no element except manganese has a cross section greater than that for iron. This is an over-simplification, of course, because commercial steels contain residual amounts of other elements introduced unintentionally with raw materials and scrap in the steelmaking process. These amounts are of the order of a few hundredths to a few thousandths of a weight percent.[11] Cobalt, counted as nickel in steelmaking alloys,[3] may be 0.08 to 0.10 pct or more of the nickel content. Tantalum is present also in the stabilized grades of type 18-8 stainless steel. For applications where sources of radioactive isotopes must be kept at a minimum, carbon steel low in manganese definitely would be superior to carbon or alloy steels with normal manganese contents.

It might be concluded from Table I that to obtain steel with a small cross section for thermal neutrons, a carbon steel should be chosen and some way found to eliminate manganese. For applications where corrosion resistance is not the primary requisite, such a steel might compare favorably with alloy steels both on the basis of mechanical properties and cost. Aside from any desirable nuclear characteristics, production of such a steel would be a technically feasible way to conserve manganese, an element whose domestic, high grade deposits are very scarce. The American Iron & Steel Institute reports importation of slightly more than 3 million tons of metallurgical

Table I. Microscopic Absorption Cross Sections for Thermal Neutrons of Elements Commonly Found in Steel[12]

Cross Sections in Barns = 10^{-24} Cm^2					
Group I		Group II		Group III	
S	0.5	Fe	2.4	B	750
Al	0.22	Mo	2.4	Co	34.0
P	0.19	N	1.8	Ta	21.3
Zr	0.18	Nb	1.1	W	19.2
Pb	0.17			Mn	12.6
Si	0.13				
C	0.0045			Ti	5.6
O	0.0002			V	4.7
				Ni	4.5
				Cu	3.6
				Cr	2.9

quality manganese ore for 1953. Domestic production for the same year was only about 150,000 tons. These incentives plus experimental data compiled in a research program on the chemistry of sulfur in steel led to the production of the carbon steels, which are to be described here.

The success in hot rolling high sulfur-low manganese steel such as a low manganese SAE/B1113 grade, and data subsequently published[8] showing that titanium or zirconium could be used to replace part of the manganese in steel, led to the decision to produce steel in an experimental open hearth without addition of manganese. The heats were cast into 7,000-lb ingots. From ingot stage to finished product the steels were produced in full size mill equipment under customary processing conditions for comparable grades with normal manganese contents.

Table II. Specifications of Normal Manganese Steels for Which Low Manganese Alternates Were Made

ASTM Grade	Composition					Tensile Requirements			
	C	Mn	P	S	Si	Tensile Strength, Psi	Yield Strength, Psi, Min.	Elongation, Pct	
								8 In.	2 In.
A212B-54aT	0.31 (max)	0.90 (max)	0.035 (max)	0.04 (max)	0.15 to 0.30	70,000 to 85,000	38,000	19	22
A106B-52T	0.30 (max)	29 to 1.06	0.043 (max)	0.058 (max)	0.10 (min.)	60,000 (min.)	35,000	—	22
A242-55	0.22 (max)	1.25 (max)	—	0.05* (max)	—	70,0000 (min.)	50,000	18	—

* May contain such additional alloys as will give the mechanical properties described.

Table III. Composition of Low Manganese Steels

Heat No.		Composition, Wt Pct									
		C	Mn	P	S	Si	Al	Cu	Ti	Zr	V
A212B	½ in. plate	0.27	0.62	0.012	0.040	0.26	—	—	—	—	—
RH-1031	Ladle	0.17	0.08	0.004	0.008	0.15	—	—	0.15	—	—
	½ in. plate	0.19	0.08	0.010	0.019	0.19	0.012	—	0.17	—	—
RH-1032	Ladle	0.23	0.10	0.006	0.014	0.25	—	—	0.14	—	—
	½ in plate	0.22	0.08	0.008	0.017	0.19	0.009	—	0.16	—	—
RH-1055	Ladle	0.33	0.20	0.017	0.011	0.30	—	—	0.47	—	—
	1 in. plate	0.33	0.19	0.020	0.021	0.25	—	—	0.44	—	—
A106B	Pipe	0.25	0.86	0.023	0.017	0.24	—	—	—	—	—
RH-1081	Ladle	0.31	0.12	0.018	0.020	0.14	—	—	0.30	—	—
	Pipe	0.31	0.13	0.019	0.021	0.16	0.019	—	0.31	—	—
A242	¾ in. plate	0.14	1.16	0.008	0.017	0.08	0.012	0.37	—	—	0.055
RH-1050	Ladle	0.12	0.16	0.012	0.013	0.13	—	0.37	0.34	—	—
	¼ in. plate	0.11	0.17	0.009	0.017	0.10	0.12	0.39	0.38	—	—
RH-1051	Ladle	0.08	0.15	0.008	0.020	0.08	—	0.38	0.45	—	—
	¼ in. plate	0.07	0.15	0.004	0.016	0.06	0.048	0.39	0.47	—	—
RH-1053	Ladle	0.06	0.07	0.005	0.022	0.09	—	0.40	—	0.32	—
	¾ in. plate	0.06	0.08	0.008	0.015	0.09	0.30	0.40	—	0.31	—

The initial goal for this work was to determine whether low manganese steels (an arbitrary 0.10 pct max Mn content was set) could be made and rolled with commercial equipment and processing conditions into products that would be acceptable commercially when evaluated by standard tests. This paper is limited to consideration of steels to which titanium or zirconium with aluminum were added in place of manganese and is regarded as a progress report rather than a summary of results of a completed research program.

Table IV. Tensile Properties of Low Manganese Steels, Grade A212B*

Property	Hot Rolled			
	A212B**	RH-1031	RH-1032	RH-1055
Tensile strength, psi	71,350	87,100	82,850	104,100
Yield point, psi	40,950	67,900†	63,600†	63,000‡
Elongation, 8 in.	26.0	17.0	17.0	17.5
	Stress Relieved—4 Hr at 1150°F			
Tensile strength, psi	66,900	85,850	80,751	104,700
Yield point, psi	37,600	57,000	50,900	64,000‡
Elongation, 8 in.	28.3	16.0	18.0	17.0
	Normalized			
Tensile strength, psi	73,200	70,900	70,200	88,000
Yield point, psi	48,800	56,750	54,800	69,800
Elongation, 8 in.	27.6	22.5	22.1	23.0

* All heats passed bend and homogeneity tests.
† Yield strength at 0.1 pct offset, psi.
‡ Yield strength at 0.2 pct offset, psi.
** Tests were from ½ in. plate; RH-1031 and RH-1032 were from ¼ in. plate; RH-1055 was from 1 in. plate.

Steelmaking

The experimental open hearth used for production of the low manganese steels was described by Work and Banta in 1939.[4] Table II gives the composition and mechanical property requirements for the grades for which low manganese alternates were made. The A212 grade B firebox quality is a boiler plate grade, the A106 is commonly used for seamless pipe, and the A242 is a low alloy, high tensile grade.

The goal of the steelmaking program was to produce steels meeting the composition requirements for the above grades with a maximum 0.10 pct Mn content. Either titanium or zirconium would be added to replace the manganese so that mechanical properties as good as those of the standard grade would result. Seven heats were made, none being discarded because of processing difficulties.

The furnace charge consisted of approximately 50 pct scrap, and 45 pct pig iron, and the remainder of limestone and burnt lime. The scrap was charged first along with 3.3 pct limestone. After the bath had melted level, the second charge consisting of pig iron and 1.7 pct burnt lime was added. The carbon content of the bath at melt down was of the order of 1 pct. Carbon was eliminated at a rate of approximately 0.01 pct per min. Oxygen was used in RH-1053 and RH-1055 to promote carbon elimination. Table III shows the composition of the heats. Heats RH-1031 and RH-1032 were deoxidized in the ladle with 3.4 lb per ton of aluminum and 6.2 lb per ton of titanium in the form of high silicon ferrotitanium. A furnace block was not used. For the remaining heats a block of 2.75 lb per ton of 11 pct ferrosilicon was used. The ladle addition of aluminum was increased to approximately 5.5 lb per ton for RH-1050, RH-1055, and RH-1081. For heats RH-1051 and RH-1053, total aluminum additions of 11 and 18 lb per ton, respectively, were made—in the former case, low silicon ferrotitanium containing 6 lb per ton of aluminum was added; in the latter case, an aluminum-zirconium alloy provided zirconium and 13 lb per ton of aluminum. Coal was added to meet the carbon specifications for the A212 grades. All heats were fully killed except

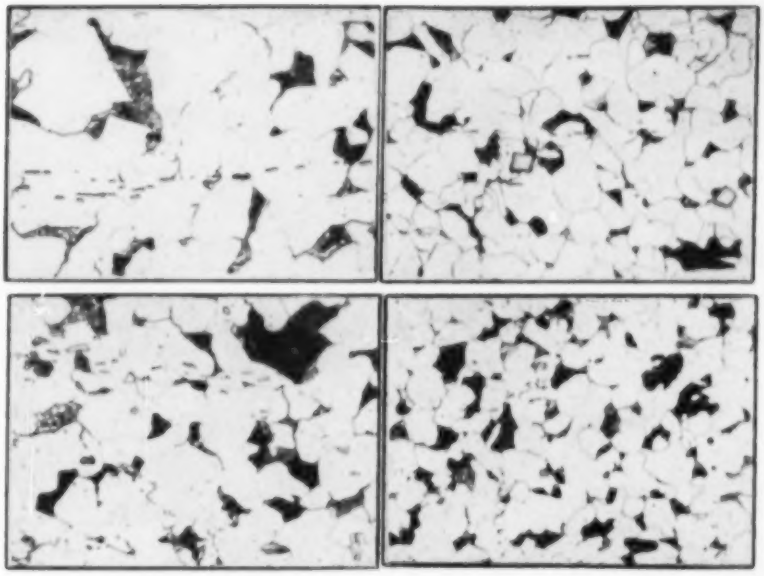


Fig. 2—Microstructures of low manganese steels. Upper left, RH-1032 as rolled; upper right, RH-1032 normalized; lower left, RH-1055 as rolled; lower right, RH-1055 normalized. Etchant 3 pct Nital. Magnification X500, reduced approximately 15 pct for reproduction.

RH-1055, which grew in the mold. All were cast in 16x32-in. big-end-up molds.

With the exception of RH-1081, the ingots were cooled to room temperature, stripped, and shipped to the Pittsburgh Works, where they were scheduled for rolling into slabs and subsequently into ¼, ½, ¾, or 1-in. plates along with production heats. The grade A106 heat (RH-1081) was shipped to the Aliquippa Works where it was rolled via 7x7-in. billets into 3¾ in. diam x 3½ ft long rounds and, subsequently, into 2⅜ in. O.D. schedule 80 seamless pipe in pieces 24 ft long.

Table V. Tensile Properties of Low Manganese Steel, Grade A106B*

Property	A106B, Hot Rolled	RH-1081		
		Hot Rolled	Annealed	
			Subcritical	Full
Tensile strength, psi	73,830	78,540	69,810	61,460
Yield point, psi	50,960	51,460	46,890	38,750
Elongation, 2 in.	39.0	24.8	26.8	27.3

* All specimens passed flattening and hydrostatic tests.

At no stage in the rolling operations were any operating difficulties reported. The surface quality and appearance of the finished material was fully as good as that of the normal manganese grades.

Following this, portions of all of the plate were hot rolled to sheet, and the sheet cold reduced to strip as light as 0.015 in. thick. The pipe was reduced to approximately ½ in. tubing without difficulty. Surface finishes were equivalent to those obtained with commercial steel of normal manganese content.

Properties

Mechanical Properties—The mechanical property tests called for by ASTM specification for the respective grades are: 1) A212: tensile, bend, and homogeneity; 2) A106: tensile, flattening, and hydrostatic; and 3) A242: tensile and bend. Tables IV to VI show these data for the low manganese steels. For each grade, representative data for a normal manganese content steel are shown also.

Low manganese material was generally stronger and somewhat less ductile than comparable grades with normal manganese content. It will be noted that RH-1055 contained more carbon than would be permissible for A212B plate of this thickness; also the silicon content was maximum. The manganese exceeded the 0.10 pct maximum set for the low manganese steels. Heats 1050 and 1051 also contained more manganese than was desired. The carbon contents of RH-1051 and RH-1053 were appreciably lower than that of the commercial A242 material tested.

Figs. 1 to 4 show the microstructures of the low manganese steels in the as-rolled and heat-treated condition. For comparison, the microstructure of a specimen of commercial grade A212B material is shown also. It should be noted that the carbon contents of RH-1050, RH-1051, and RH-1053 are considerably lower than those of the other steels.

Table VI. Tensile Properties of Low Manganese Steels, Grade A242*

Property	Hot Rolled			
	A242†	RH-1050	RH-1051	RH-1053†
Tensile strength, psi	71,400	83,150	59,850	59,950
Yield point, psi	48,300	73,650	None	37,450
Elongation, 2 in.	31.2	24.2	31.0	35.5
	Stress Relieved—4 Hr at 1150°F			
Tensile strength, psi	71,050	81,800	59,600	54,300
Yield point, psi	50,210	70,700	None	40,250
Elongation, 2 in.	29.5	26.5	30.2	36.5
	Normalized			
Tensile strength, psi	66,835	63,550	49,750	54,800
Yield point, psi	54,440	52,850	None	41,100
Elongation, 2 in.	35.0	30.5	39.5	34.5

* All steels passed bend tests.
† Tests were from ¾ in. plate; RH-1050 and RH-1051 were from ¼ in. plate.

Table VII gives tensile properties and hardness values for the low manganese plate after quench-

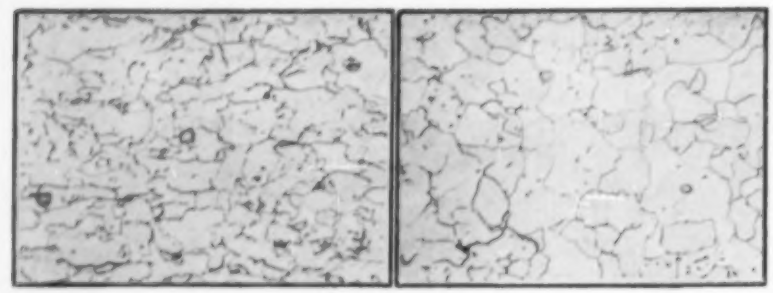
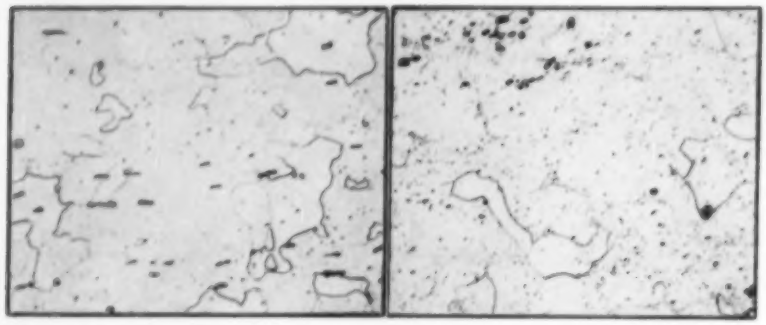


Fig. 3—Microstructures of low manganese steels. Upper left, RH-1050 as rolled; upper right, RH-1050 normalized; lower left, RH-1051 as rolled; lower right, RH-1051 normalized. Etchant 3 pct Nital. Magnification X500, reduced approximately 15 pct for reproduction.



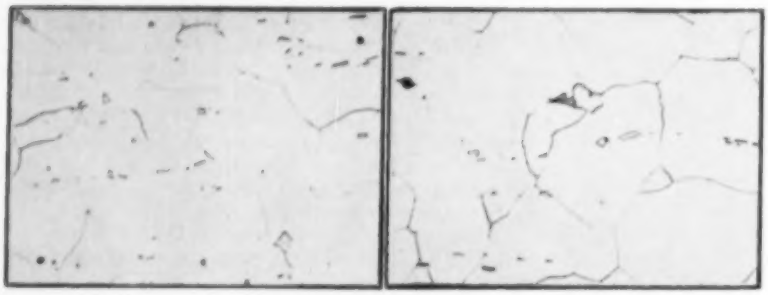
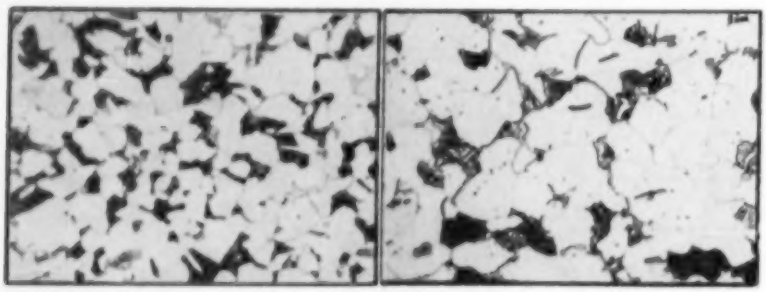
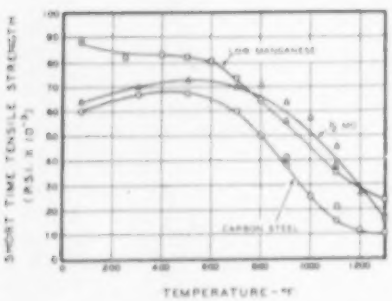


Fig. 4—Microstructures of low manganese steels. Upper left, RH-1053 as rolled; upper right, RH-1053 normalized; lower left, RH-1081 as rolled; lower right, RH-1081 annealed at 1650°F. Etchant 3 pct Nital. Magnification X500, reduced approximately 15 pct for reproduction.





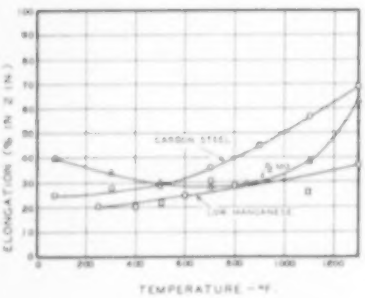


Fig. 5—Short-time tensile strengths for low manganese and normal manganese steels.

Table VII. Tensile Properties of Quenched and Tempered Low Manganese Steels

Heat No.		Temperature, °F Quenched	Tempered	Yield Strength, 0.1 Pct Offset, Psi	Tensile Strength, Psi	Elongation, 2 In., Pct	Reduction, in Area, Pct	Hardness, Rb
RH-1032	½ in. plate	1675	600	68,200	92,700	26	65.7	96
			800	64,100	87,300	30	60.3	92
			1000	58,500	81,400	34	65.7	86
			1100	57,900	81,300	28.5	69.8	86
			1200	56,900	79,700	27.5	66.6	85
		2000	600	69,200	91,200	30	71.6	—
			800	66,900	88,400	30.5	71.5	92
			1000	62,900	84,000	30	58.8	85
			1100	65,700	85,300	31	63.8	92
			1200	64,000	86,600	31	67.3	90
RH-1050	¼ in. plate	1675	600	48,500	83,000	30.5	79.2	76
			800	50,200	64,700	34	79.2	75
			1000	48,800	62,300	33.5	77.1	73
			1100	47,900	62,100	33	74.5	73
			1200	49,900	62,100	31.5	76.1	76
		2000	600	73,000	87,900	24	73.2	93
			800	73,700	89,300	26.5	69.1	93
			1000	76,700	90,100	25	71.5	92
			1100	76,800	88,000	26	67.9	92
			1200	79,300	93,200	21.5	67.9	95
RH-1051	¾ in. plate	1675	600	25,900	52,700	37	71.5	59
			800	28,400	53,800	37.5	70.1	59
			1000	27,100	53,100	37.5	70.7	—
			1100	25,600	53,300	37.5	71.7	57
			1200	26,500	53,600	37.5	77.0	59
		2000	600	68,000	82,400	19	61.3	95
			800	66,300	79,500	18.5	56.7	81
			1000	74,800	87,000	21.5	57.6	—
			1100	75,300	89,250	21	61.0	90
			1200	61,300	78,100	22.5	65.0	74
RH-1053	¾ in. plate	1675	600	34,300	54,900	41.5	65.5	68
			800	34,100	55,200	41	63.0	67
			1000	33,300	54,300	41.5	66.3	67
			1100	31,700	52,900	43	66.0	66
			1200	32,300	53,700	42.5	62.5	60

ing from 1,675° and 2,000°F and tempering at selected temperatures from 600° to 1,200°F.

Information on the transition temperature and impact behavior of plate steels, such as are covered by ASTM grade A212B specifications, has been summarized by McGeady[7] who concluded that little information was available. McGeady's study was of data on pressure vessel steels. In Table VIII are ferrite (ASTM) grain size and Charpy keyhole impact values at room temperature and at 0°F for low manganese specimens. The values for the quenched and tempered specimens are the average for the conditions given in Table VII. Data on the transition temperature and impact behavior of the low manganese steels are incomplete, and the values in Table VIII are presented as preliminary information only. The ductile to brittle transition temperature for the low manganese steels in the as-hot-rolled condition are higher than usually obtained on standard grade A212B material of the same thickness processed in the same way.

Elevated temperature, i.e., short time, tensile tests were made over the range from room temperature to 1300°F. The tensile strengths of the low manganese steels at these temperatures are shown in Table IX. Fig. 5 compares the tensile strength and elongation of the low manganese with similar data for carbon steel and a manganese-molybdenum grade. The low manganese material is superior to the normal manganese material and as good as the ½ pct Mo material. Table X shows the change in tensile strength from room temperature to 500°F for selected low manganese steels. By this criterion, the low manganese steels are not susceptible to strain aging. RH-1050 was least satisfactory in this respect. Data on standard carbon steel plate and pipe at elevated temperatures have been presented by Enzian,[8] by Miller,[4] and by Simmons and Cross.[11]

Weldability tests were made by joining the low manganese steels to commercial A212 plate and to stainless steel of the 347 (Nb stabilized) and 304 type. Welds were made with the coated metal-arc and inert-gas shielded tungsten arc processes. The material welded satisfactorily in all cases with no evidence of porosity or cracking. Tests included face bend tests, guided side bend tests, and rectangular tensile strength measurements on dissimilar weld plates. Tests were pulled transverse to the weld direction. The composite samples welded together with different types of electrodes all had sound welds. In every case the specimen failed outside the weld and heat affected zone. All data, including X-ray examination, indicated the low manganese materials welded as well as or better than comparable commercial normal manganese grades.

Chemical Properties—By proper choice of raw materials, carbon steel can be produced with very low amounts of residual elements. Data on their level in scrap are given by Sullivan.[10] He does not include data for such elements as tantalum or cobalt, which are usually very low in carbon steel unless introduced in scrap. Manganese and iron, then, are the major constituents of carbon steel and are likely to be the major corrosion products in any medium to which they are exposed.

Corrosion tests in water have shown that low manganese steels in the as-rolled condition corrode at substantially the same rate as the normal manganese steels. The manganese content of the corrosion product is, however, substantially lower.

Table VIII. Impact and Grain Size Data for Low Manganese Steels

Identity	Heat Treatment	Keyhole Charpy, Ft-Lb 0°F	Keyhole Charpy, Ft-Lb Room Temperature	Ferrite Grain Size, ASTM No.
A212	Normalized	28	34	8
RH-1032	Normalized	4	28	8
	Quenched and tempered	37	49	—
RH-1055	Normalized	21	36	8
A242	Hot rolled	38	53	6
	Stress relieved	33	51	6
	Normalized	65	71	8
RH-1053	Hot rolled	30	41	8
	Stress relieved	33	47	6
	Normalized	31	49	6
	Quenched and tempered	35	45	—

Table IX. Elevated Temperature Tension Test Results for Low Manganese Steels

Heat No.†	Test Temperature, °F	Tensile Strength, Psi	Elongation, 2 In., Pct	Reduction of Area, Pct
RH-1031	Room	87,400*	15.5*	47.5*
	250	83,080	20	59.5
	400	83,260	20	60.1
	500	82,880	20.5	61.6
	600	81,580	24	59.2
	700	73,600	31.5	66.9
	800	62,500	29	73.5
	1100	36,400	36	78.1
	1300	24,700	33	82.5
RH-1032	Room	89,450*	17*	42*
	250	81,000	21.5	56.3
	400	81,580	20.5	56.2
	500	81,250	23.5	55.6
	600	79,500	25	59.4
	700	73,300	28.5	17.8
	800	62,000	35.5	77.2
	1100	35,000	25.5	76.0
	1300	23,700	41	86.1
RH-1050	Room	83,150	24	70.5
	250	78,850	21.5	67.1
	400	82,600	20.5	67.2
	500	82,460	21	58.9
	600	80,040	30	64.2
	700	70,700	32.5	65.3
	800	61,500	32.5	76.5
	1100	34,800	27.5	66.5
	1300	24,600	30	75.0
RH-1051	Room	59,900	31	77.7
	250	48,690	29	73.5
	400	46,150	27.5	70.9
	500	46,300	27	75.3
	600	44,150	25	70.3
	700	41,900	24.5	69.9
	800	40,400	24.5	75.0
	1100	30,700	25.5	71.3
	1300	19,600	26.5	82.8

* 8 in. gage; all others, 2 in.
† Heat treatment: as rolled.

Data on scaling, creep, and graphitization at high temperatures are not available for the low manganese steels. There is reason to expect they will prove equal or superior to those for grades with normal manganese levels. Manganese, along with aluminum, has been reported to lower resistance to creep and graphitization, while carbide formers such as titanium increase resistance.

The effect of hydrogen on mechanical properties of the low manganese steels at elevated temperatures and pressures has not been evaluated. Ordinary carbon steels may be severely damaged by such exposure; strong carbide-forming elements in the steel will prevent or lessen its severity. Titanium is considered one of the most effective.[5, 6, 9, 10]

Both titanium and zirconium have a strong affinity for sulfur. Their presence, together with the low manganese content, may make low manganese steels resistant to liquid metal attack under conditions which would decarburize or desulfurize standard carbon steels. Also, the deleterious effect of sulfur on welding characteristics may be minimized.

Titanium and zirconium combine readily with nitrogen; their presence in low manganese steels may prove of value in applications where gas-metal reactions at high temperature are important.

Summary

Experimental carbon steels made with no manganese addition and residual manganese contents of the order of 0.10 to 0.15 pct have been made by standard open hearth practice and rolled with commercial equipment and procedures into plate and seamless pipe. These products when tested by ASTM methods met the mechanical property requirements for comparable grades with normal manganese contents.

Elevated temperature tensile data show the low manganese steels to be free from strain aging and stronger and more ductile at elevated temperatures than comparable standard grades. Weldability of the low manganese steels is equal to or better than that of comparable standard grades.

Table X. Hot Tensile Test Data for Low Manganese Steels

Identity	Tensile Strength, Psi: Room Temperature	Tensile Strength, Psi: 500°F	Change, Psi
A212B	71,350	75,240	+3,890
RH-1031	87,400	82,880	−4,520
RH-1032	89,450	81,250	−8,200
A242	71,400	69,150	−2,250
RH-1050	83,150	82,460	−750
RH-1051	59,850	47,840	−12,010

Acknowledgment

The writer acknowledges with pleasure the cooperation and assistance of his associates, and the management of Jones & Laughlin Steel Corp. for its support of work on the low manganese steels and its permission to publish results.

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Technical Note

Experimental Determination of Oxygen in Cupola-Melted Cast Iron

by E. A. Loria, H. W. Lownie, Jr., and M. W. Mallett

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MANY investigations have been made of the residual gas content of iron and steel. Very few, if any, quantitative measurements have been made on the oxygen content of cupola-melted iron.[1] The fact that cast iron is a complex alloy rather than

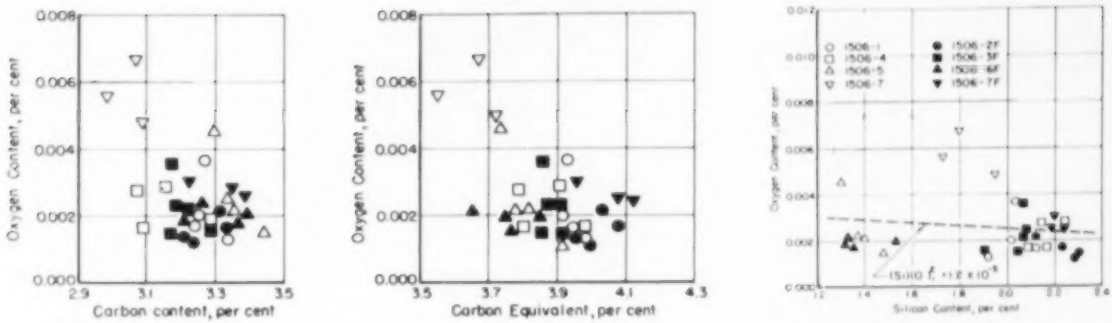

Fig. 1—Relation of oxygen content of cast iron to its carbon content, carbon equivalent, and silicon content. Hollow and solid symbols refer to two series of heats made at different times according to the cupola practices given in Table I.

a simple binary alloy, and is melted under the dynamic conditions attendant to cupola operation makes it worthwhile to determine what the oxygen content of cast iron would be under both oxidizing and normal melting practice and how close the values follow the equilibrium values calculated from the deoxidation constant for the Si-O reaction.

Vacuum fusion oxygen values are presented for cast iron melted in the Battelle 10 in. diam cupola under normal operating practice and under the oxidizing conditions described in Table I. The nominal composition of the iron at the spout was that of a typical automotive grade, about 3.20 pct C and 2.10 pct Si. Cupola slag and metal samples were taken simultaneously from five to seven taps spaced through each heat. The metal specimens for vacuum-fusion analyses were poured in split steel molds that produced a clean pin, ⅜ in. in diam and 2 in. long. All collected slags were typical of commercial slags used in acid cupolas.

Acceptance of steel deoxidation theory[1] leads to the following conclusions regarding the oxygen content of cast irons of the type involved in this investigation:

1) The oxygen content of the iron can be expected to be low, probably about 0.002 to 0.003 pct.

Table I. Relation of Oxygen in Metal and Slag for Cast Irons Melted in Small Cupola under Different Operating Conditions

Heat*	Tap	Metal Analysis, Pct by Weight						Slag
		TC	Si	CE	O_2	H_2	N_2	FeO
1506-1	6	3.24	2.12	3.95	0.0017	0.00023	0.008	3.47
	10	3.26	2.04	3.94	0.0037	0.00038	0.012	4.50
	17	3.25	2.01	3.92	0.0020	0.00018	0.007	7.75
	21	3.34	1.92	3.98	0.0013	0.00020	0.007	11.30
	Average	3.27	2.04	3.95	0.0022	0.00025	0.009	6.76
1506-2F	6	3.23	2.28	3.99	0.0012	0.00011	0.007	3.67
	9	3.21	2.29	3.97	0.0013	0.00019	0.007	3.73
	17	3.34	2.23	4.08	0.0017	0.00015	0.010	4.17
	21	3.32	2.12	4.03	0.0021	0.00011	0.011	4.75
	Average	3.28	2.23	4.02	0.0016	0.00014	0.009	4.08
1506-3F	6	3.18	2.08	3.87	0.0023	0.00033	0.007	4.29
	9	3.17	2.03	3.85	0.0015	0.00033	0.008	5.69
	13	3.16	2.07	3.85	0.0036	0.00056	0.007	5.93
	17	3.21	2.06	3.90	0.0021	0.00027	0.006	5.14
	21	3.28	1.90	3.91	0.0015	0.00026	0.007	9.05
	Average	3.20	2.03	3.88	0.0022	0.00035	0.007	6.04
1506-4	6	3.07	2.13	3.78	0.0028	0.00023	0.007	8.49
	9	3.09	2.14	3.80	0.0020	0.00020	0.008	11.50
	13	3.08	2.15	3.80	0.0016	0.00046	0.007	10.00
	17	3.15	2.24	3.90	0.0029	0.00015	0.007	9.80
	21	3.27	2.06	3.96	0.0016	0.00026	0.009	10.50
	Average	3.13	2.14	3.84	0.0022	0.00026	0.008	10.07
1506-5	9	3.34	1.40	3.81	0.0021	0.00022	0.008	11.50
	13	3.30	1.30	3.73	0.0046	0.00030	0.007	16.40
	16	3.34	1.39	3.80	0.0021	0.00029	0.006	13.50
	19	3.43	1.46	3.92	0.0015	0.00018	0.008	14.70
	Average	3.37	1.40	3.82	0.0026	0.00025	0.007	14.00
1506-6F	9	3.24	1.53	3.75	0.0020	0.00009	0.009	11.70
	13	3.21	1.33	3.65	0.0021	0.00037	0.013	10.90
	16	3.39	1.32	3.83	0.0020	0.00016	0.007	8.35
	19	3.35	1.32	3.79	0.0019	0.00022	0.009	9.57
	Average	3.31	1.41	3.78	0.0020	0.00021	0.009	9.63
1506-7	7	3.09	1.96	3.74	0.0049	0.00031	0.007	8.73
	8	2.96	1.72	3.55	0.0056	0.00020	0.008	8.99
	10	3.06	1.80	3.66	0.0068	0.00057	0.004	10.55
	Average	3.04	1.83	3.65	0.0058	0.00036	0.006	9.43
1507-7F	20	3.39	2.19	4.12	0.0025	0.00020	0.007	2.69
	21	3.21	2.20	3.94	0.0030	0.00022	0.010	2.50
	23	3.34	2.23	4.08	0.0023	0.00023	0.009	4.62
	Average	3.32	2.21	4.05	0.0027	0.00022	0.009	3.27
1507-9F	6	3.06	2.28	3.82	0.0024	0.00021	0.007	4.07
	9	3.11	2.32	3.88	0.0015	0.00023	0.008	3.70
	13	3.08	2.26	3.83	0.0022	0.00014	0.007	—
	17	3.19	2.33	3.97	0.0015	0.00020	0.007	3.30
	21	3.12	2.48	3.96	0.0014	0.00018	0.007	4.38
	Average	3.10	2.33	3.89	0.0015	0.00019	0.007	4.36

* Heats 1 and 2F—good operating conditions in 10 in. diam cupola. Heats 3F and 4—low tapping temperature and high degree of oxidation; lowered blast temperature and increased blast volume. Heats 5 and 6F—greater degree of oxidation; use of lightweight, rusty scrap and low bed height. Heats 7 and 7F—increased blast rate on low bed height. Heat 9F—recycled scrap used under normal operation.

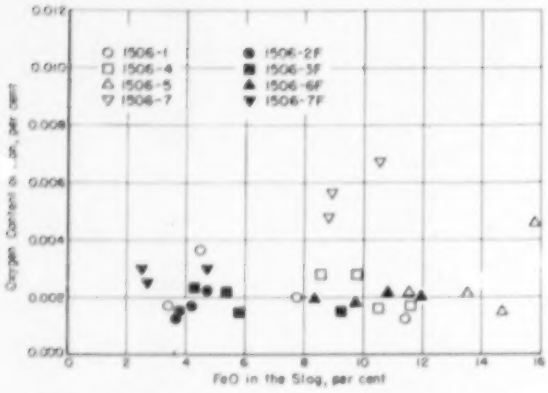

Fig. 2—Relation of FeO in the slag to oxygen content of the iron.

2) An increase in the silicon content of the iron by as much as 1 pct Si can be expected to have little effect upon the oxygen content of the iron.

3) A change in the operating temperature of the cupola, within commercial limits, can be expected to have little effect upon the oxygen content of the iron.

Individual vacuum-fusion results for oxygen, hydrogen, and nitrogen for each sample analyzed in this investigation are given in Table I. The results of cupola heats and vacuum-fusion analyses for oxygen agreed with deoxidation theory as follows:

1) With the exception of Heat 1506-7, the average amount of oxygen found in irons melted in this investigation was about 0.002 pct.

2) Changes in the silicon content of the iron from 1.32 to 2.35 pct had no consistent effect on the oxygen content of the iron. This is shown in Fig. 1. Also, the oxygen content of the iron had no detectable relationship to either a) the carbon content of the iron, within a range of 2.98 to 3.43 pct, or b) the carbon equivalent of the iron, within a range of 3.55 to 4.12 pct, as shown in Fig. 1.

3) Within a range of tapping temperatures from 2650° to 2800°F, there was little change in the average oxygen content of the iron.

The data in Fig. 2 show, for the limited range of oxygen contents, that FeO contents in the slag had a wide range, from about 3 to 15 pct. Also, the reduction of FeO in the slag is not accompanied by any marked reduction in the oxygen content of the iron, and there is no consistent relationship between the FeO content of the slag and the oxygen dissolved in the iron. This means that the partition factor in cupola-melted iron does not vary in a significant way under the conditions of the data.

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Gas Content of Solid Aluminum by Solid Extraction and Vacuum Fusion

The determination of hydrogen in aluminum by two methods, solid extraction and vacuum fusion, and the preparation of suitable samples are described. Analyses of similar aluminum specimens by the two methods agree. In addition, results by solid extraction agree with those obtained on duplicate samples exchanged with the Research Laboratories of the British Aluminium Co. Little additional hydrogen is evolved in the vacuum fusion of a sample already degassed by a solid extraction.

by James L. Brandt and C. Norman Cochran

ALTHOUGH gas in aluminum and its effect on aluminum products have been the subject of a number of papers, not many quantitative determinations of the hydrogen content of solid aluminum and its alloys have been recorded in the literature. For solid aluminum samples, four investigators have reported hydrogen contents which appear reasonable compared with the hydrogen solubility of 0.7 ml per 100 g, STP, in molten aluminum at 660°C established by Ransley and Neufeld[1] and verified by Opie and Grant[2] and Ransley and Talbot.[3] Sloman,[4] who used a vacuum fusion procedure, reported the hydrogen content of some high purity aluminum as 0.66 ml per 100 g, STP. Griffith and Mallett,[5] employing the tin fusion method, reported the internal hydrogen content of six different aluminum alloys as ranging from less than 0.1 ml per 100 g, STP, for 1100 alloy to 0.7 ml per 100 g, STP, for 4043 alloy (previously 43S, a 5 pct Si alloy). Eborall and Ransley,[6] using a solid extraction of the gases at 600°C, reported hydrogen contents ranging from 0.1 ml per 100 g, STP, to 1 ml per 100 g, STP. Ransley and Talbot reported that several thousand analyses on 99.2 pct and higher purity aluminum as well as Duralumin type alloys indicated hydrogen contents ranging from 0.1 ml per 100 g, STP, to 0.5 ml per 100 g, STP.

J. L. BRANDT and C. N. COCHRAN are associated with Physical Chemistry Div., Aluminum Co. of America, New Kensington, Pa.

TP 4289D. Manuscript, Dec. 6, 1954. Chicago Meeting, February 1955.

In a recent article, Kostron[1] reviewed the physical and chemical methods used in the laboratory for determining the gas content of light metals, and stated that the most accurate and reproducible results are obtained by hot extraction in a vacuum. Although other investigators have indicated good reproducibility by either hot extraction or vacuum fusion, no investigator has used both methods to determine the hydrogen content of aluminum. The apparatus and procedures for determining hydrogen content of solid aluminum by solid extraction at 550° to 600°C and vacuum fusion in a tin bath will be described.

Apparatus

Extraction Assembly—For solid extraction the sample is heated to approximately 50 Centigrade degrees below its melting point in a Vycor extraction tube which is connected to the analytical portion of the system.

In the vacuum fusion apparatus, the melting assembly consists of a graphite crucible insulated from an outer quartz envelope by boron nitride powder. Into this crucible a second graphite crucible, in which the melting of the samples takes place, is fitted. Samples are guided into this melting crucible by means of a graphite funnel. A Lepel 7.5 kw high frequency induction furnace is employed to heat the assembly.

Analytical Assembly—Both systems have essentially the same analytical arrangement shown schematically in Fig. 1. Gases extracted from the sample are led to the analytical manifold through a cold trap, stopcock, and mercury diffusion pump. This manifold is evacuated through a large bore mercury seal stopcock (hereafter called the main stopcock) by a second mercury diffusion pump backed by a mechanical pump. Mercury cutoffs in both systems make it possible to isolate the analytical portion of the system. Beyond the cutoff, condensable vapors may be removed by a cold trap. A McLeod gage is sealed into the manifold for pressure measurements. An arm leads from the manifold to a bulb in which a palladium tube is sealed. This bulb is heated to between 300° and 400°C by an external furnace, at which temperature hydrogen in the gas diffuses through the palladium tube and is collected by the third mercury diffusion pump. A line leads from this pump through the analysis stopcock back into the manifold.

In operation, the gas is collected, the cutoff raised, and the pressure read. The analysis stopcock is closed, and the hydrogen is allowed to diffuse through the palladium tube. The fraction of hydrogen collected is determined from the pressure with the analysis stopcock open minus the equilibrium pressure with the analysis stopcock closed. The volume of the gas from the sample is the total gas collected minus a correction for outgassing of the system. This correction is the product of the time the gas is collected and the rate for outgassing established at the beginning of each run.

Known amounts of hydrogen diffused rapidly through the palladium when the tube was new. Continued operation at temperatures above 450°C increased the time for hydrogen analysis from 10 or 15 min to 2 or 3 hr. The palladium tube could be regenerated in place, however, by the method described by Lombard, Eichner, and Albert.[2] This involved heating the palladium tube in air at 500°C for 1 hr, followed by reduction in hydrogen for 1 hr at 150°C. Continued operation at 300° to 400°C after

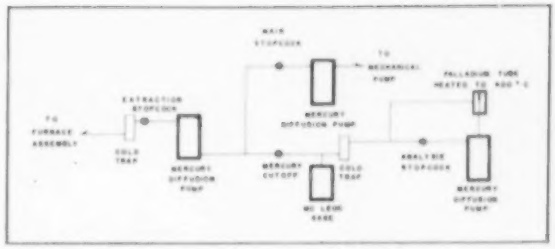

Fig. 1—Schematic diagram of solid extraction or vacuum fusion apparatus.

regeneration caused no additional poisoning of the tube. Hydrogen analyses are performed in 20 min.

Procedure

Solid Extraction Apparatus—The Vycor or quartz extraction tube in the solid extraction apparatus is outgassed overnight at 850° to 900°C. The temperature is lowered to between 550° and 575°C, and the blank for the system established. The sample is pushed into the hot zone by means of a glass ram into which a soft iron piece has been sealed so that this may be operated with external magnets. Gas is collected until the rate of collection declines to the blank value established at the beginning of each run. The gas is analyzed for hydrogen, after which the system is evacuated in preparation for the next run.

Vacuum Fusion Apparatus—The melting assembly is heated at a temperature of 1800° to 2000°C for a few hours, and the temperature is lowered to 650°C. The tin samples are pushed into the hot zone to form a heel for the aluminum samples and, after a few minutes, the main stopcock is closed. After establishing the blank correction, the sample is dropped into the hot zone. Melting and gas evolution are completed in 10 to 12 min, after which the hydrogen analysis is performed.

Sample Preparation

Surface Control—One of the most difficult problems in determining the true internal hydrogen content of aluminum samples is control of the surface gas. Early experiments of filing samples in a dry box always led to hydrogen values 5 to 10 times the true internal hydrogen content. With dry machining and subsequent degreasing in CP benzene,* the surface gas is reduced to low values which do not mask out the true internal hydrogen content of an aluminum sample.

* This method of preparation was suggested by Drs. Smithells and Ransley of Research Laboratories, British Aluminium Co.

Surface Gas Correction—The surface gas correction was determined on several cylinders degassed in the solid extraction apparatus. The procedure involved facing off the ends and machining 0.015 in. from a cylinder immediately after it had been analyzed, followed by standard benzene degreasing. These samples were loaded in the solid extraction apparatus and analyzed for hydrogen, with the assumption that any gas evolved would be hydrogen from the surface. With improvements in technique, the surface gas correction was lowered to the value of 3.5×10^{-4} ml per cm^2. For a cylinder $\frac{5}{8}$ in. diam and 1½ in. long, the surface gas correction is 0.04 ml H per 100 g, STP, i.e., approximately 15 pct of the total hydrogen found in samples of low gas content.

Results

Table I summarizes the results obtained by solid extraction and vacuum fusion on electrical conduc-

tivity grade rod (99.45 pct minimum aluminum content) and 1175 alloy (99.75 pct minimum aluminum) gassed and degassed by various techniques.

In addition to samples run in the Aluminum Co. of America Laboratories by the two different methods, a section of the electrical conductivity standard rod was analyzed in England under the direction of C. E. Ransley, of the British Aluminium Co. His results on this rod showed the hydrogen content to be about 0.20 ml H per 100 g, STP, in comparison with values of 0.26 ml and 0.31 ml H per 100 g, STP, by the two methods in the Aluminum Co. of America Laboratories.

Table I. Summary of Hydrogen Analyses on Aluminum Specimens

Specimen	Method of Determination	No. of Analyses	Average Hydrogen Content, Ml per 100 G, STP	Standard Deviation, Ml per 100 G, STP
Electrical conductivity rod	Solid extraction	31	0.26	±0.08
Electrical conductivity rod	Vacuum fusion	17	0.31	±0.08
1175*	Solid extraction	14	0.29	±0.08
1175*	Vacuum fusion	11	0.24	±0.08
1175†	Solid extraction	1	0.86	—
1175†	Vacuum fusion	3	1.03	±0.07
1175‡	Solid extraction	2	0.97	—
1175‡	Vacuum fusion	3	1.00	±0.13

* Specimen was degassed with chlorine.
† Specimen was gassed with ammonia.
‡ Specimen was gassed with steam.

Samples prepared at the Research Laboratories, British Aluminium Co., were analyzed with the objectives of checking the authors' solid extraction procedure and sample preparation. Half of these British Aluminium Co. samples were machined dry and degreased in benzene in England and sealed in evacuated glass vials, and the other half were prepared in the Aluminum Co. of America Laboratories. For the two samples prepared in England, hydrogen contents in the Aluminum Co. of America Laboratories were 0.27 and 0.23 ml H per 100 g, STP, in comparison with the British Aluminium Co. results on similar specimens of 0.27 ml H per 100 g, STP. For the samples machined and degreased in the Aluminum Co. of America Laboratories, the hydrogen contents were 0.24 and 0.28 ml per 100 g, STP, still in good agreement with the results obtained at the Research Laboratories, British Aluminium Co.

Discussion

Using a diffusivity[5] for hydrogen in aluminum at 550°C of 1.6×10^{-4} cm² per sec, a cylinder $\frac{5}{8}$ in. diam should have 99 pct of the hydrogen removed in 65 min. Since the sample must be heated in vacuum from room temperature to the extraction temperature and the natural oxide film may slow down diffusion somewhat, 3 hr or longer is used in actual practice for gas determinations.

To test the effectiveness of solid extraction, a resistance furnace was placed around the sample arm in the vacuum fusion apparatus so that samples could be degassed by the solid extraction procedure and melted without the necessity of breaking vacuum between runs. In these experiments, the specimens of 1175 aluminum, which had been gassed with either steam or ammonia, were placed in the sample arm and degassed 6 hr at 500°C. (The hydrogen content of these specimens is shown in Table I to be about 1 ml per 100 g, STP). Four specimens degassed in this manner showed residual hydrogen contents of 0.02 ml per 100 g, 0.04 ml per 100 g, 0.04 ml per 100 g, and 0.05 ml per 100 g on fusion. This is a convincing demonstration of the effectiveness of solid extraction for aluminum samples.

Conclusions

1) With properly prepared specimens, reproducible hydrogen contents of aluminum alloy samples can be secured by either solid extraction or vacuum fusion.

2) Exchange of samples with the Research Laboratories, British Aluminium Co., gives additional evidence for the reproducibility of the results.

3) Because of the rapidity with which analyses can be obtained, vacuum fusion has a decided advantage over solid extraction.

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Method for Spectrochemical Determination Of Aluminum in Fe-Al Alloys

by Edward F. Runge and Ford R. Bryan

BECAUSE of the need for ductile heat resistant alloys of non-strategic composition, there has been metallurgical development of Fe-Al alloys possessing improved ductility and hot strength, together with high oxidation resistance. Iron and aluminum form solid solutions up to approximately 35 pct Al. Alloys in the 8 to 12 pct Al range are characterized by excellent oxidation resistance, high electrical resistivity[1] and, when appropriately alloyed, have creep rupture strength equivalent to that of the austenitic stainless steels.[2] At higher aluminum levels, the magnetic properties are of considerable interest. Nachman and Buehler[3] have recently reported on the desirable magnetic characteristics of the 16 pct alloy.

E. F. RUNGE and F. R. BRYAN are with the Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

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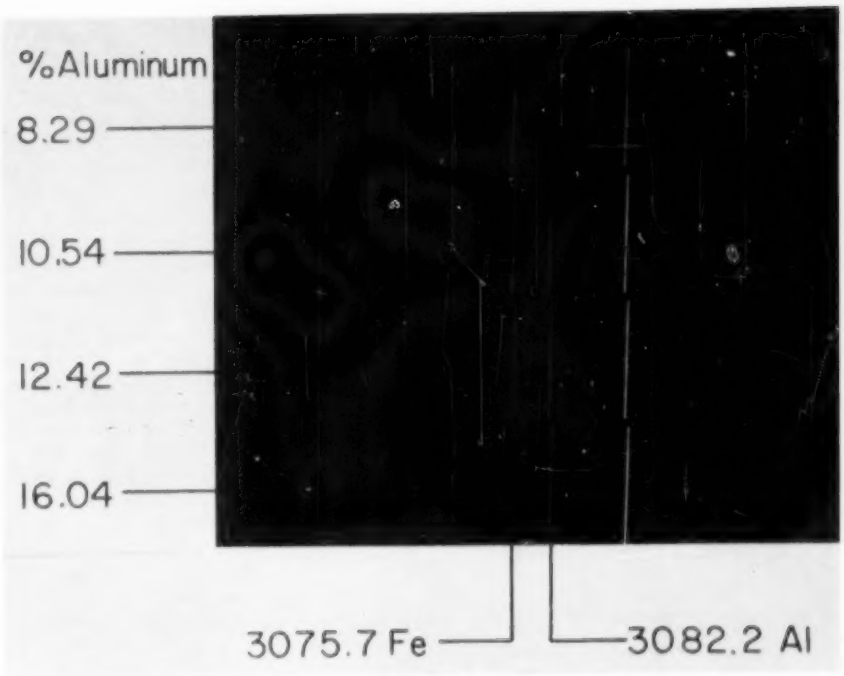

Fig. 1—Littrow spectra identifying aluminum analytical line and internal standard iron line.

Dependency of physical properties upon the exact aluminum content requires that production control analysis be provided in order to maintain optimum aluminum concentration for the intended purpose. A rapid analytical method is therefore necessary for the commercial success of these alloys. There is no procedure given in the literature for the analysis of these Fe-Al alloys.

This paper describes a straightforward spectrochemical procedure exhibiting high precision and adaptable to either photographic or direct reading instruments. The method provides for the determination of aluminum in the concentration range between 8 and 16 pct, and is designed for routine control purposes. A photographic version of the method is described here in detail.

Samples in the form of 5.0 mm diam rods are excited by a high-voltage controlled spark using a counter electrode of pure iron. The analytical gap is flushed with nitrogen during the excitation period. After the spectra are recorded on a photographic plate, the intensity ratios of a pair of lines, one from aluminum and one from the internal standard iron, are determined with a microphotometer and standard transposing equipment. The photographic emulsion is calibrated by means of a set of standard iron arc lines for which relative intensities have been previously determined. The concentration of aluminum is read from an analytical curve, prepared from standard samples, which relates the log intensity ratio of the line pair to the log of the aluminum concentration.

Equipment used in the method is described below, and is commercially available from various instrument suppliers. Excitation is by means of a high-voltage condensed ac spark unit. The discharge circuit consists of the usual transformer, inductor, condenser, resistor, and an auxiliary air gap by which the frequency of the discharge can be varied. The spectrograph employed is a Bausch and Lomb large quartz Littrow prism mounting having a plate factor of 4.5A per mm at 3000A, and covering the

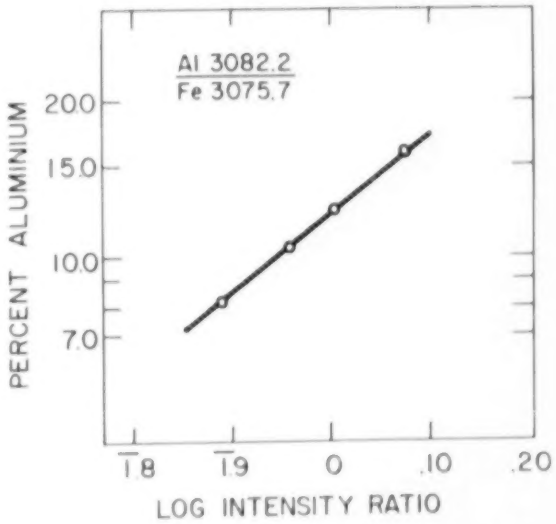

Fig. 2—Analytical curve relating log intensity ratio of the line pair to log of the aluminum concentration.

spectral region from 2680A to 3950A in this method.

The spectrum is recorded on an Eastman Spectrum Analysis No. 1 plate, and the transmittances of the spectral lines are measured on a non-recording, projection-type microphotometer. A calculating board upon which the Hurter-Driffield emulsion calibration curve' is plotted is employed to convert microphotometer readings to intensity ratios.

Plates are processed in a thermostatically controlled developing machine, washed in running water, and dried in a stream of warm air.

The standards used to prepare the analytical curve were prepared from material which had been vacuum melted and poured into the form of small 15 lb ingots. The ingots were sampled and analyzed chemically for aluminum content. The chemical

Table I. Emulsion Calibration Lines

Wavelength, A	Relative Intensity
3142.4	0.945
3153.2	1.111
3157.0	1.345
3157.8	1.225
3160.6	1.428
3165.0	0.690
3214.0	2.360
3215.0	1.786
3230.9	1.600
3239.4	1.955

Table II. Coefficient of Variation*

No.	Pct $T_{mtls.\ 1}$ Fe	Pct $T_{mtls.\ 2}$ Al	Log I/I_0	Pct Al	d
1	60.0	62.0	$\bar{1}.98$	10.80	0.31
2	60.0	63.0	$\bar{1}.97$	10.70	0.11
3	62.0	65.5	$\bar{1}.97$	10.70	0.11
4	64.5	67.5	$\bar{1}.97$	10.70	0.11
5	65.0	69.5	$\bar{1}.96$	10.54	0.05
6	69.0	72.0	$\bar{1}.97$	10.70	0.11
7	70.0	75.0	$\bar{1}.96$	10.54	0.05
8	70.0	75.0	$\bar{1}.96$	10.54	0.05
9	70.0	75.0	$\bar{1}.96$	10.54	0.05
10	71.0	76.0	$\bar{1}.96$	10.54	0.05
11	73.0	78.0	$\bar{1}.96$	10.54	0.05
12	74.0	78.5	$\bar{1}.96$	10.54	0.05
13	74.0	78.5	$\bar{1}.96$	10.54	0.05
14	74.0	78.5	$\bar{1}.96$	10.54	0.05
15	75.0	79.5	$\bar{1}.96$	10.54	0.05
16	75.0	80.0	$\bar{1}.96$	10.54	0.05
17	75.0	80.0	$\bar{1}.96$	10.54	0.05
18	77.0	80.5	$\bar{1}.96$	10.54	0.05
19	77.0	81.0	$\bar{1}.96$	10.54	0.05
20	78.0	82.0	$\bar{1}.96$	10.54	0.05
		Spectrographic concentration avg		10.59	
		Chemical concentration avg		10.54	

*From the equation

$$p = \frac{100}{C}\sqrt{\frac{\Sigma d^2}{n-1}} = 0.93 \text{ pct.}$$

where C equals concentration; d equals deviation from the mean; n equals number of determinations; and p is the coefficient of variation.

procedure employed in analyzing the spectroscopic standard is the cyanide-oxine method and requires 3 to 4 hr for a determination, which far exceeds the time available for production control, but is suitable for occasional standardization.

A representative sample for spectrographic analysis is prepared by machining the metal into a rod of a few inches length and 5.0 mm diam. The rod is further prepared for analysis by grinding a conical point of 140° included angle on one end. The electrode system consists of two rods, the sample rod and a rod of pure iron having the same diameter and conical tip. The rods are placed in spring clamps and spaced to a gap of 2 mm. A cylinder of compressed nitrogen is used to produce a jet of inert gas, which is directed between the electrodes and onto the electrode tips at a flow rate of 20 cu ft per hr.

Excitation parameters of the spark discharge circuit are as follows: peak secondary voltage, 14,000 v; capacitance, 0.007 microfarads; inductance, 10 microhenries; resistance, 2.0 ohms; average secondary current, 8.5 amp; auxiliary gap, 3.6 mm; and No. of discharges per sec, 360. Spectrograph settings and exposure conditions are as follows: spectral region, 2680 to 3950A; entrance slit width, 20 μ; entrance slit length, 3 mm; prespark period, 20 sec; and exposure period, 25 sec.

Calibration of the emulsion (normally only once for each emulsion lot No.) is effected by separate stepped exposures of an iron arc spectrum. These exposures provide a group of lines of known relative intensities[4] which are plotted against their corresponding transmission values to produce the characteristic Hurter and Driffield curve. The lines, together with their assigned relative intensities, are presented in Table I.

Any conventional photographic processing procedure is appropriate. The conditions listed below were used for convenience in this work, although much faster processing can be accomplished, if necessary, by employing Eastman D-8 developer together with shorter washing and drying times: emulsion, Eastman Spectrum Analysis No. 1 plates; development, Eastman D-19 developer agitated for 3 min at 68°F; stop bath, dilute acetic acid for 30 sec; fixing, Eastman Rapid Liquid Fixer for 1 min; washing, running tap water for 3 to 5 min, followed by distilled water rinse; and drying, warm air blast for 3½ min.

Spectral line transmittance measurements are made on the projection-type microphotometer for the analytical line Al 3082.2A and the internal standard line Fe 3075.7A. These two lines are identified in the spectra shown in Fig. 1. Exposure conditions are selected to provide transmittance measurements between 20 and 80 pct. The transmittances of the analytical and the internal standard lines are converted to log intensity ratios by means of the emulsion calibration curve. Carrying this procedure through for the standard materials serves to establish an analytical curve, Fig. 2, relating log intensity ratio to log concentration for the pair of lines. The corresponding log intensity ratios from the spectra of unknown samples are converted into known concentrations by referring to the analytical curve.

The repeatability of determinations made on a single sample exposed under identical conditions provides a measure of precision. The coefficient of variation obtained in this manner on a sample midway in the concentration range proved to be 0.9 pct of the amount of aluminum present. Table II illustrates individual determinations from which deviations were calculated. The values shown agree favorably with repeatability data on other elements analyzed in similar fashion and occurring in alloys in like concentrations. Deviations were more than double those shown when the nitrogen jet was omitted from the procedure.

The accuracy of the method can be established by comparison of the spectrographic results with results obtained by other methods of analysis. When cross checking against hydrostatic density, electrical resistivity, and chemical results, spectrographic values should agree within ±0.10 to 0.15 pct Al in the 8.0 to 16.0 pct concentration range.

References

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[2] E. R. Morgan and V. F. Zackay: Ductile Iron-Aluminum Alloys. *Metal Progress*, 1955, vol. 68, No. 4, pp. 126-128.

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[5] G. H. Dieke: Study of Standard Methods for Spectrographic Analysis. War Production Board Report No. W-90, March 20, 1944.

Discussion of this paper sent (2 copies) to AIME by May 1, 1957 will appear in AIME *Transactions* Vol. 209, 1957, and in JOURNAL OF METALS, October 1957.

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AIME NEWS

Surprises in Store at Annual Meeting

Highlighting the social program planned for the Annual Meeting in New Orleans is the Informal Dance and moonlight sail aboard the S.S. President, on Tuesday February 26. The floor show, scheduled for midnight, will feature a comic magician MC, a singing duo and a dance team. In addition to accordian and guitar music, an eight-piece orchestra will provide dance music for the guests. Soft drinks and beer will be sold.

The traditional Welcoming Luncheon is set for 12 noon, February 25, at the International Room of the Roosevelt. After an address by the guest speaker, awards will be presented to winners of local section membership and student prize paper contests. Souvenirs will be furnished by the Freeport Sulphur Co.

The International and Grand Ballrooms of the Roosevelt Hotel will accommodate the 1600 guests attending the Annual Banquet on Wednesday, February 27 at 7 pm. Prior to dinner, a reception will be held in the Wildcatter Room for Head Table guests. During the banquet, background music will be played by the Bert Peck String Ensemble, with entertainment beginning at midnight.

"For men only", the dinner-smoker at the Roosevelt on Monday, February 25, at 7:30 pm, will feature "excellent stag entertainment."

To Speak at Metals Dinner

Clayton Rand, editor of *The Dixie Guide* and owner of the Dixie Press at Gulfport, Miss., will address the Metals Branch dinner during the AIME Annual Meeting in New Orleans. The dinner is scheduled to be held in Room No. 1, Hotel Jung, Tuesday evening, February 26.

Mr. Rand is well known as a popular convention and after-dinner speaker and is one of the most articulate editors in the country. He has a reputation as a dynamic, humorous speaker. Born in Wisconsin, he was reared in Mississippi and worked his way through Mississippi State College as a peanut vendor and through Harvard Law School by selling cooking utensils. In addition to practicing law, he bought a country weekly newspaper in 1919 and has owned five newspapers. He is past president, Mississippi State Press Assn. and National Editorial Assn.

1957 ANNUAL MEETING
METALS BRANCH SOCIAL FUNCTIONS

SUNDAY, FEBRUARY 24

6:30 P.M. — Mineral Industry Education Division Dinner

MONDAY, FEBRUARY 25

12:00 Noon — Welcoming Luncheon
6:00 P.M. — Cocktail Party
7:30 P.M. — Dinner-Smoker, Stag Dinner and Entertainment

TUESDAY, FEBRUARY 26

Metals Branch Social Hour and Dinner
6:00 P.M. — Social Hour
7:00 P.M. — Dinner
Speaker, Clayton Rand, Editor, *The Dixie Guide*

10:00 P.M to 2 A.M — Informal Dance aboard S. S. President

WEDNESDAY, FEBRUARY 27

12:15 P.M. — Extractive Metallurgy Div. Luncheon
7:00 P.M. — Annual Banquet and President's Reception

THURSDAY, FEBRUARY 28

12:15 P.M. — Powder Metallurgy Luncheon

Will Address Electric Furnace Steel Meeting

E. R. JOHNSON

Ernest R. Johnson, vice president in charge of operations, Republic Steel Corp., will address the Electric Furnace Steel Conference at the annual dinner on December 6 in the Morrison Hotel, Chicago. Mr. Johnson will speak on *Men, Money and Machines*. Edward C. Logelin, vice president, U. S. Steel Corp., Chicago, will be toastmaster.

Mr. Johnson, a native of Chicago, has had a notable career; a series of promotions with Republic led to his appointment as vice president in 1954.

Successful IMD Fall Meeting in Cleveland

The men who worked behind the scenes are shown above, from left to right: C. S. Barrett, IMD Chairman; R. W. Shearman, IMD Secretary; and F. C. Crawford, guest speaker at the annual dinner.

The Carter Hotel in Cleveland was the scene of this year's highly successful Fall meeting of the AIME Institute of Metals Division. Total registration was reported at 846. Held October 8-10, 1956, coincidentally with the National Metal Congress and Exposition, it was estimated that more than 85,000 men from all branches of the metals industry were in Cleveland for various meetings and to attend the show.

Highlight of the technical sessions was the Fifth Annual Symposium on Titanium. An overflow audience crowded into the Grand Ballroom of the Carter Hotel to hear talks and discussions on the economics of production and fabrication of titanium in the morning session, and an equally large audience was present at the afternoon session, which was devoted to analytical developments, and the control of interstitials. For those who were unable to attend the symposium, the January issue of the JOURNAL OF METALS will contain the complete proceedings, including all talks and discussions by the panel members.

Two other symposiums were on the program, one on magnetism and the other on nuclear metallurgy. The papers presented on nuclear metallurgy have been printed and are available from the AIME as Volume III of the *Nuclear Metallurgy Series*. The price for AIME members is $2.50.

At the annual dinner on Tuesday, F. C. Crawford, Chairman of the Board of Thompson Products Inc., gave an address, entitled, *Geometric Progression—Yardstick of the Future*.

The Programs Committee, under the Chairmanship of M. E. Nicholson, scheduled ten separate sessions for summaries of research and seminars on particular topics. In all, more than 70 papers were read, and the IMD once again showed itself to be a lively and active group which does more than a little toward carrying out the goals of the AIME.

Powder Metallurgy Luncheon

Carl J. Johnson of Presmet Corp., chairman of the AIME Powder Metallurgy Committee, greeted the 65 luncheon guests at the Carter Hotel, Cleveland, Wednesday, October 10, during the National Metal Exposition. The luncheon, a semi-annual gathering of powder metallurgists, featured informal talks by E. C. Nelson, Dept. of Metallurgy, Rensselaer Polytechnic Institute, and J. L. Bonanno, The Lionel Corp. Dr. Nelson's subject was *Education in Powder Metallurgy in American Colleges*, and Mr. Bonanno spoke on *Standardization in Powder Metallurgy Today*.

Dr. Nelson emphasized three major considerations in teaching powder metallurgy: subject matter; the place for powder metallurgy courses in the curriculum; and the necessity for providing separate powder metallurgy courses. He pointed out a serious shortcoming—a lack of information on the principles of design in powder metallurgy—and presented a typical course outline and a listing of colleges offering undergraduate and graduate courses in powder metallurgy.

Mr. Bonanno described the early industry efforts at standardization, traced the beginning of the Metal Powder Assn., now specialized to include Electronic Core, and Ferrite Committees, the establishment and growth of ASTM B-9, of which he is currently chairman, with its eight subcommittees and 21 existing or pending powder metallurgy specifications. He called attention to stapdardization efforts by military establishments. In concluding, Mr. Bonanno stated that thus far it has not been possible to establish universal powder specifications, adding that the principal task in standardization at present is the collecting and collating of data rather than undertaking new standards.

The cocktail party before the annual dinner afforded the opportunity for renewing old friendships. Shown above are A. B. Kinzel, AIME President-Elect for 1958; and C. E. Reistle, Jr., current President.

Ernest Kirkendall, AIME Secretary, enjoys a pleasant moment with R. F. Hehemann, Chairman of the Cleveland Section, and W. R. Hibbard, Jr., Vice Chairman of IMD.

Shown just before the annual dinner of the IMD are, left to right: C. S. Barrett, IMD Chairman; C. E. Reistle, Jr., AIME President; John Chipman, ISD Chairman; A. O. Schaefer, ASM President; and W. R. Hibbard, Jr., Vice Chairman of IMD.

Record Turnout For NOHC Eastern Section Meeting

A record of 291 registrants attended the meeting of the Eastern Section, National Open Hearth Steel Committee, held at Hotel Warwick, Philadelphia on Friday, Oct. 12. The day's program featured technical sessions in the morning and afternoon, and a fellowship dinner in the evening.

After opening remarks by C. D. Moore, Section Chairman, who is vice president of G. and W. H. Corson Inc., the prize winning paper of the section was presented to the award winner, Gene M. Haggenberger, Baldwin-Lima-Hamilton Corp., Burnham, Pa. His paper was entitled, *The Effects of Improved Combustion Conditions in a Cold Metal Shop.*

A panel discussion followed, devoted chiefly to refractories. R. Russell Fayles, Lukens Steel Co., was moderator. Panelists included Keith Bartles, U. S. Steel Corp.; Gardner Blythe, C. F. & I. Corp.; E. E. Collinan, Alan Wood Steel Co.; James Chisham, and Richard Stanford, Bethlehem Steel Co.; Russell Farr, American Steel & Wire Co.

Following a luncheon in the Mirror Room, Hotel Warwick, the afternoon session was opened with a paper on *An Automatic Fuel Control System*, presented by Donald R. Mathews, Alan Wood Steel Co. Mr. Mathews explained how a system was installed to utilize excess coke oven gases in the open hearth furnace, and control their use automatically. The second talk by Frank Bird, Kukens Steel Co., was on *Safety Salesmanship*, and emphasized the importance of having a good product to sell. He added that safety must be properly "packaged", and understanding created through proper communications.

Refractories in the open hearth furnace, a comparison of the results from use of basic refractories, contrasted with silica refractories, was described in a paper by W. S. Debenham, U. S. Steel Corp., Pittsburgh. *Factors Affecting Ingot Quality* was the subject of a paper by A. L. Lehman of Bethlehem Steel Co. The author, discussing the analysis of steel, showed how such factors as the best temperature at top, a nozzle of the right size, cleanliness, and good pouring practice are important in obtaining quality ingots.

The last paper, *The Use of Direct Reading Spectrometer*, by John Scott, was read by his colleague at Lukens Steel Co., H. B. Potter. Use of a spectrometer in place of traditional methods of chemical analysis has speeded up the time in which an analysis can be made, and as a result, heat time is reduced 10 to 15 min. Furthermore, training time for operators of the equipment has been cut drastically.

Chairmen for the afternoon technical session were Harry Davis, Bethlehem Steel Co., and J. D. Sutherland, U. S. Steel Corp.

At the Fellowship Dinner, held in the Grand Ballroom of Hotel Warwick, C. D. Moore presided as Toastmaster. Speaker of the evening was Dan R. Loughrey, Jones & Laughlin Steel Co., who reviewed the history of open hearth steelmaking from its earliest days and pointed out that the good life in America today is due, in large measure, to the constantly increasing production of steel and use of steel products. Mr. Loughrey discussed, among new developments, the direct reduction of iron ores to metallic iron, oxygen use in making quality steel directly from iron, the hot extrusion of steel, the continuous casting of billets and slabs, and the beneficiation and agglomeration of low-grade ores.

During the dinner hour, diners were entertained by Joe Jovinelly at the accordian, Dave Monahan at the xylophone, and a popular singing duet, Ned Smith and June Sayre.

Officers of the Eastern Section, NOHC, are: C. D. Moore, chairman; G. S. Baldwin, Baldwin-Lima-Hamilton Corp., vice chairman; and J. R. Behrman, Alan Wood Steel Co., secretary. Also contributing to the success of the October meeting were Clyde B. Jenni, General Steel Castings Corp., Eddystone, Pa., who arranged the program, R. L. Botteiger, chairman of the suppliers committee, and his committee—A. E. Bickel, J. W. Corriston, C. L. Corson, J. J. Edmiston, and L. U. Park.

Successful Globetrotters Fall Meeting in Colorado

The NOHC Southwestern Section, *The Globetrotters*, held a successful Fall meeting at the Broadmoor, Colorado Springs, Colo., on September 27 and 28, with the Colorado Fuel & Iron Corp. playing host to the 175 registrants and 71 wives. A breakfast at the Minnequa Club and tour of the C. F. & I. plant in Pueblo were the featured events of the first day.

Seven papers and a prepared discussion highlighted the technical sessions on Friday, Sept. 28. *Human Aspects of Shop Production* was the topic of George Grosvenor and C. F. Henzelman, while Art Schoenebeck discussed the *Installation of Prefabricated Front Buckstays*. Other papers presented were: *Increasing Scrap Density to Reduce Charging Time*, by S. M. Purcell; *Recent Developments in the Use of Oxygen*, by Gene Miller; *Recent Substitution of Basic Brick in Open Hearth Construction, Including Checkers*, by A. H. Sommer; *Mechanical Aids to Open Hearth Repairs*, by M. H. Weir; and *Mechanical Repairs to Open Hearth Furnaces*, by D. Taylor.

The section elected to give a prize paper award for the first time this year, and found it necessary to split the award between two equally deserving papers. Authors Lewis B. Lindemuth, Jr., and Roger E. Ragain divided the $100 prize.

Among the social events were a cocktail party, for men only, given by E. J. Lavino & Co. on Thursday at the Garden of the Gods Club, and a cocktail party and fellowship dinner in the ballroom of the Broadmoor on Friday evening. The ladies were feted with a luncheon and a tour of the high spots in and around Colorado Springs on Friday.

Arrangements for the meeting were made by J. M. Brashear, with Glenn Siemiller guiding the technical sessions.

Annual Fall Meeting of NOHC Buffalo Section

The Seventh Annual Fall Meeting of the Buffalo Section, National Open Hearth Steel Committee was held in the Statler Hotel, Buffalo, on November 13, and once again proved lively and interesting. Total registration was over 200, of which about 100 made the plant trip through the Tonawanda Forge of General Motor Corp.'s Chevrolet Division. This is one of the most modern, highly automated forge shops in the country.

The afternoon technical session featured three stimulating talks, each of which was followed by a lively discussion. *Open Hearth Safety* was the first topic, delivered by J. W. Tysse, manager of safety for Republic Steel Corp. Mr. Tysse stressed the need for vigilance before accidents happen, and brought out that "brainstorming" sessions, used extensively in other fields, have proved most successful in developing new safety techniques.

The part that open hearth plays in steel quality was the subject of the second talk, delivered by R. D. Hindson, assistant chief metallurgist with the Steel Co. of Canada. Mr. Hindson attacked the problem from many angles, with striking illustrations showing some defect at the ingot stage, and then the resulting imperfections in finished strip.

A more than lively discussion resulted from the third talk, which was on the subject of extra high firing rates for maximum production. Presented by J. D. Sloane, assistant melting foreman, Steel Co. of Canada, the subject was obviously one of great interest, as Stelco has been experimenting with the highest firing rates ever used in an open hearth.

The American and Canadian flags flanking the speakers' platform at the Annual Dinner gave the meeting a truly international flavor. Speaker for the evening was C. F. Luck of the New York Telephone Co., who gave a most entertaining and informative talk on *The Transistor—The Mighty Mite*, tracing its development, and demonstrating its varied applications.

1957 Publications Policies Established

Pursuant to Article X of the by-laws of the AIME, the following information is hereby given as to the "conditions, prices, and terms under which the various classes of members, and Student Associates, severally, shall be privileged to obtain publications of the Institute during the ensuing year."

Publications authorized for issue in 1957 include the following: MINING ENGINEERING, published monthly, containing material, including technical papers, of interest to those engaged in exploration, mining geology and geophysics; metal, nonmetallic, and coal mining and beneficiation; and fuel technology. The JOURNAL OF METALS, published monthly, containing material, including technical papers, of interest to those engaged in nonferrous smelting and refining, iron and steel production, and physical metallurgy. The JOURNAL OF PETROLEUM TECHNOLOGY, published monthly in Dallas, containing material, including technical papers, of interest to those engaged in petroleum and natural gas drilling and production.

Annual subscriptions to any one of the above journals will be provided all members in good standing without further charge, a subscription credit of $6 for members and $4 for Student Associates being included in the dues paid. (A member ceases to be in good standing if current dues are not paid by April 1). If more than one of the monthly journals is requested, $4 extra will be charged for an annual subscription, or 75¢ for single copies of regular issues and $1.50 for special issues. The nonmember subscription price for each journal is $8 in the Americas and U. S. possessions; foreign, $10; for single issues 75¢ in the Americas; $1.00 foreign for regular issues; $1.50 for special issues. Student Associates will be entitled to the same privileges for all publications as members. AIME members subscribing to more than one of each of the three monthly journals will be billed at the nonmember rate of $8 per year, domestic; $10 foreign, for the extra subscription(s).

Three volumes of "*Transactions*" are authorized for 1957 publication, as follows: No. 205, Mining Branch; No. 206, Metals Branch; and No. 207, Petroleum Branch. Volumes 205 and 207 will be available to members at $3.50 each for a first copy if paid for in advance with dues; otherwise at the nonmember rate of $7 less 30 pct. Nonmembers $7 in the United States; foreign $7.50. Volume 206 will be available to members at $4.50 each for a first copy if paid for in advance with dues; otherwise at the nonmember rate of $9 less 30 pct. Nonmembers $9 in the United States, foreign $9.75.

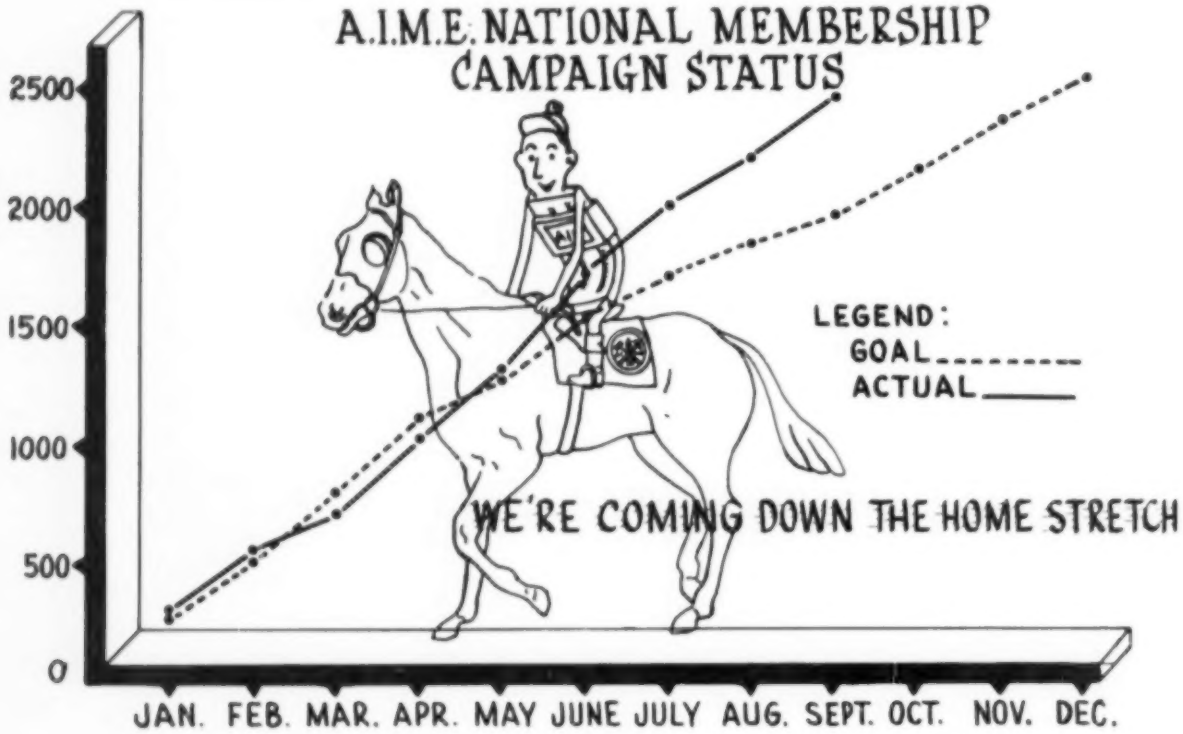
Special volumes now planned for publication in 1957 include the following: *Open Hearth Proceedings*, Vol. 40, price to AIME members $7; nonmembers $10. *Blast Furnace, Coke Oven, and Raw Materials Proceedings*, Vol. 16, price to AIME members $7; to nonmembers $10. *Electric Furnace Steel Proceedings*, Vol. 14, price to AIME members $7; to nonmembers $10. *Statistics of Oil and Gas Development and Production*, Vol. 11, covering data for the year 1956, AIME members $5; nonmembers $10. *Porphyry Coppers*, 2d edition, by A. B. Parsons, price to be determined. *A New Look at the Nature of the Open-Hearth Process*, by B. M. Larsen, $2 to AIME members, $3 to nonmembers. *Physical Chemistry of Steelmaking—Deoxidation of Steel*, by C. H. Herty; price to be determined. Volume on Mineral Economics, price to be determined. 1957 AIME Directory.

If dues are paid subsequent to January 31, back issues of Institute publications will be supplied only if adequate stocks are on hand. A member is not entitled to receive a volume of *Transactions*, or a special volume, in lieu of a monthly journal, free of charge on membership. Members in arrears for dues are not entitled to special members' prices for publications.

Rocky Mountain Members may have their choice of an annual subscription to one of the monthly journals on request.

Howe Lecturer Named

Maxwell Gensamer has been selected to be the Howe Lecturer at the Annual Meeting in New York, 1958. Dr. Gensamer is Professor of Metallurgical Engineering, School of Mines, Columbia University.



All-Institute Session During Annual Meeting

For the first time, an All-Institute Meeting is scheduled during the Annual Meeting in New Orleans. A prominent speaker will address the meeting at 2 pm on Tuesday, February 26th in the International Room at the Roosevelt Hotel, New Orleans. Following that, at 4 pm, the Annual Business Meeting of the AIME will be held in the same place. At a recent meeting of the AIME Board of Directors, the fourth Tuesday of February was approved for this latter meeting instead of the third Tuesday as is indicated in the AIME bylaws.

AIME Awards Announced

The following honors will be conferred at the annual banquet on Wednesday, February 27, 1957 at the Roosevelt Hotel, New Orleans.

Charles F. Rand Medal to **Andrew Fletcher,** "For distinguished administration in nonferrous mining and metallurgical enterprises; for his inspiring leadership in the mineral industry; and for his outstanding contributions toward furthering the professional interests of those engaged in the mineral industries."

James Douglas Medal to **Russel B. Caples,** "For distinguished achievement in extractive metallurgy, particularly in the electrowinning of zinc; and for outstanding success in stimulating the professional careers of many metallurgists."

Anthony F. Lucas Medal to **J. E. Brantly,** "For contributions to the art of drilling; for technical writing including the *Rotary Drilling Handbook*; and for leadership in the petroleum industry, notably in founding the American Association of Oil Well Drilling Contractors."

Benjamin F. Fairless Award to **Leo F. Reinartz,** "For distinguished achievement in production and in technology. For unerring guidance to the beginning metallurgist, invaluable advice to the operator. For inspiration to both."

Robert H. Richards Award to **Antoine Marc Gaudin,** "For his contributions as a scientist, educator, and author; specifically for his leadership and direction in the development of leaching and recovery techniques for low-grade uranium ores."

Robert W. Hunt Medal to **Arthur Tix.** Silver Medal for paper, *Production-Scale Vacuum Steel Degassing.* JOURNAL OF METALS, April 1956.

Rossiter W. Raymond Award to **Mohamed Mortada,** for paper *A Practical Method for Treating Oilfield Interference in Waterdrive Reservoirs.* JOURNAL OF PETROLEUM TECHNOLOGY, December 1955.

Mathewson Medal to **Paul Gordon,** for paper, *Microcalorimetric Investigation of Recrystallization of Copper.* JOURNAL OF METALS, September 1955.

J. E. Johnson, Jr. Award to **R. W. Sundquist,** "For his ability as a Blast Furnace Operator in assisting in the development of new techniques and his contributions to the Blast Furnace Literature."

D. C. Jackling Award to **Joseph L. Gillson.**

Extractive Metallurgy Div. Award to **R. C. Bell, G. H. Turner,** and **E. Peters,** for paper, *Fuming of Zinc from Lead Blast Furnace, Slag—A Thermodynamic Study.* JOURNAL OF METALS, March 1955.

Robert Peele Award to **Louis A. Panek,** for paper, *Analysis of Roof Bolting Systems Based on Model Studies.* MINING ENGINEERING, October 1955.

1957 Officers Elected

At the November Board meeting, the officers of the AIME for 1957, and six other Directors named to take office for three-year terms in that year, were officially declared elected. They are as follows: President-Elect, A. B. Kinzel; Vice Presidents, E. C. Babson and Roger V. Pierce; Directors, Luther Campbell, T. C. Frick, F. W. Strandberg, A. W. Thornton, J. S. Vanick, and Lamar Weaver.

ECPD Representatives

AIME representatives on the Engineers' Council for Professional Development for the year beginning October 26, 1956 have been named by the Board as follows: Committees: Guidance, F. T. Sisco and J. R. Van Pelt; Education and Accreditation, John C. Calhoun, Jr., and Lysle E. Shaffer; Student Development, Curtis L. Wilson; Recognition, R. E. Kirk; Training, Marion Semchysen; Ethics, Clyde Williams; Information, R. A. Beals. The three representatives on the Council are: R. F. Baker, Oct. '58, John Fox, Oct. '57, and J. P. Nielsen, Oct. '59.

Dues Bills in Mail

Pursuant to Article II, Section 2, of the bylaws of the AIME, notice is hereby given that dues for the year 1957 are payable January 1, 1957, as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter, $17; Student Associates (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed during the middle of November. Prompt payment will assure uninterrupted receipt of the publications desired in 1957. If, for any reason, a bill is not received within a reasonable time, headquarters should be notified.

Conference on High-Temperature Materials

The AIME Cleveland Section, in cooperation with the High-Temperature Committee of the Institute of Metals Div., will hold a two-day conference on high-temperature materials April 16-17, 1957, in the Hotel Carter, Cleveland.

Since the needs for higher operating temperatures make the development of new materials imperative, the conference plans to cover the classes of materials that are attractive for these applications; their properties, effects of methods of preparation and evaluation.

Subjects of papers and discussions will include, cobalt, nickel, chromium, and molybdenum base alloys; refractory metals; SAP type materials; cermets and hard metal compounds; ceramics, graphite, and methods of testing; effect of atmosphere on high-temperature properties; and effects of vacuum melting.

AIME Names 1957 Legion of Honor

Each year at the Annual Banquet in February, those members of the AIME who have continuously maintained their membership for 50 years are given special recognition. They are seated at the head table as guests of the Institute and are added to the membership of the Legion of Honor. Those who will achieve this status in 1957 are as follows:

Anderson, Alexander
Fullerton, Calif.
Brown, John T., Jr.
Pittsburgh, Pa.
Cook, Frederick S.
Mill Valley, Calif.
Dunster, C. B.
San Rafael, Calif.
Faneuf, S. C.
Berkeley, Calif.
Fisher, Norman R.
Montreal, Canada
Harrington, George B.
Chicago, Ill.
Hayward, Carle R.
Cambridge, Mass.
Knight, Cyril W.
Port Credit, Canada
Kruttschnitt, Julius
Brisbane, Australia
Lindberg, Carl O.
New York, N. Y.
Marshall, S. M.
Palo Alto, Calif.
McKechnie, B. E.
Carlsbad, N. M.
Rhodes, Fred N.
Takapuna, N. Z.
Ross, James G.
Thetford Mines, Canada
Sears, Stanley C.
Washington, D. C.
Shaw, S. F.
San Antonio, Texas
Weekes, Frederic R.
New York, N. Y.
Welhaven, Alf
Los Altos, Calif.

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To the Members of the American Institute of Mining, Metallurgical, and Petroleum Engineers Inc.:

The regular Annual Business Meeting of the Institute will be held on Tuesday afternoon, the 26th day of February 1957 following the All-Institute session at the Annual Meeting of the Institute in New Orleans.

Since the Annual Business Meeting in 1957 will be held on the *fourth* Tuesday of February instead of the *third* Tuesday as the Bylaws direct, due notice is hereby given of this change.

By Order of the Board,
Ernest Kirkendall, Secretary

Dated: Nov. 16, 1956
New York, N. Y.

On the Agenda For Spring

The Metals Branch wishes to draw the members' attention to the following Spring meetings:

Mar. 10-16, 1957—EJC Second Nuclear Engineering and Science Congress, Convention Hall, Philadelphia.

Mar. 18-19, 1957—AIME Regional Conference on Deep Drawing Steels, Engineering Society of Detroit, Detroit.

Apr. 8-10, 1957—AIME 40th Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conference, Penn-Sheraton Hotel, Pittsburgh.

Apr. 11-13, 1957—AIME Pacific Northwest Regional Conference, Multnomah Hotel, Portland, Ore.

Apr. 16-17, 1957—AIME Regional Conference on High-Temperature Alloys, Hotel Carter, Cleveland.

May 28-29, 1957—AIME Regional Conference on Reactive Metals, Ambassador Hotel, Los Angeles.

Spring 1957—AIME New England Regional Conference, Boston.

AROUND THE SECTIONS

• The **Detroit Section** has scheduled a regional meeting on March 18-19, 1957 in the Rackham Building. Drawing-quality steels is the subject, and the first day will be devoted to steelmaking aspects. Producers will discuss technical developments concerning melting, refining, rolling, and annealing. On the agenda for the second day are papers from consumers of drawing steels on specifications, applications, and testing. Also slated are papers on physical metallurgy of deep drawing steels.

A cocktail party and social hour are planned prior to the banquet on Monday, March 18. Registration is $5.00 and $4.50 for the cocktail party and banquet. AIME members will receive bound volumes of the technical papers presented. For advance registration, write to: M. Semchyshen, Climax Molybdenum Co., 14410 Woodrow Wilson Ave., Detroit 38.

• The **El Paso Metals Section** held its October meeting in the Mirror Room of the Hotel Cortez on the 10th of the month. Dysart E. Holcomb, president of Texas Western College, delivered the featured address on *Engineering Education*.

• The **New York Section** met November 15, at the Mining Club at which time they heard guest speaker Tom Winston, foreign correspondent, McGraw Hill World News, discuss *The Situation in the Middle East*. Mr. Winston, who recently returned from Beirut, covered the background and current problems in that area, with particular emphasis on raw materials. This dinner meeting was also membership night, and all were invited to bring prospective members.

Three industrial films are now available at no cost, from Christensen Diamond Products Co. Offered for showings at association meetings or conventions, these films are all 16 mm color with sound and average 25 min. Any one film or all three, may be obtained.

Film 1 deals with diamond production in South Africa and shows how diamonds are recovered from the famous Kimberly Mine and from alluvial deposits. Of special interest to those who have seen or used diamond bits in the field, Film 2 shows how these bits and barrels are manufactured. Through the eye of the camera, the viewer takes a brief tour of the Christensen plant in Salt Lake City.

Film 3 shows the application of diamond products and their use in the petroleum, mining, and construction industries. Address requests for these films to: Christensen Diamond Products Co., P. O. Box 387, Salt Lake City 10, Utah. In the event of any duplication in requests, the parties concerned will be advised and arrangements made for rescheduling.

Modern Talking Picture Service Inc. is offering a brochure which describes 30 sponsored films on various scientific topics. Among the sponsors represented are Monsanto, Dow, DuPont, Upjohn, Bethlehem Steel, and Conveyor Equipment Manufacturers Association. Most of the films are concerned with applied science, research, or technical vocations. The announcement is called *Modern Memos*, **and may be had, free, by writing to** *Modern Talking Picture Service Inc., 3 East 54th Street, New York City 22.*

The Dept. of Chemistry of the University of Chicago, in cooperation with International Film Bureau Inc., has re-edited and re-recorded three films originally produced for the British Iron and Steel Federation in its Chemistry of Iron Making Series. *What Goes Into the Blast Furnace* **(15 min., $70) shows in detail the preparation and handling of ore, coke, limestone, and air, through animated drawings and natural photography.** *Iron Making* **(13 min., $65) gives a detailed description of the chemical processes and main formulas involved in iron making, showing the chemical changes which take place in the several parts of the blast furnace.** *What Comes Out of the Blast Furnace* **(8 min., $45) depicts molten iron, castings, and the handling and use of slag. All three films are available from** *International Film Bureau Inc., 57 East Jackson Boulevard, Chicago 4, Ill.*

Trukveyors are shown in use, above.

Pathway to Profits **is a new 12 min film on Trukveyors, in-the-floor type conveying systems for moving four-wheel platform trucks. This 16 mm sound, color film illustrates how Trukveyors can solve many problems of handling merchandise shipments, reduce operating costs on railroad terminals, warehouses, etc. The movie is available free upon written request to** *Public Relations Dept., Link-Belt Co., Prudential Plaza, Chicago 1, Ill.*

A new 16 mm, sound, color film on artificial respiration is available. The 12 min movie, *No Time To Spare*, **emphasizes the importance of immediate application of respiration in different types of accidents where asphyxiation results, such as electric shock, carbon monoxide poisoning and near drowning. The techniques of artificial respiration are demonstrated by non-professionals in typical cases. Technical advisors include Warren Clayson, of the Canadian Red Cross and M. G. Griffith, professor at the University of Toronto. Produced by Chetwynd Films Ltd., the movie may be purchased from** *International Film Bureau Inc. 57 E. Jackson Blvd., Chicago,* **for $125, (includes educational and TV rights).**

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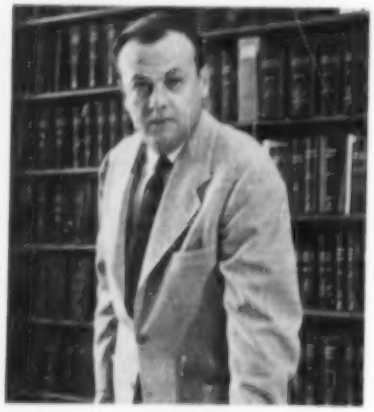
PERSONALS



J. H. HOLLOMON

J. Herbert Hollomon has been named advisory editor for *Series on the Science and Technology of Materials* to be published by John Wiley & Sons Inc., New York. The general plan of this new series is "to present the science and technology underlying the behavior and the manufacture and the technical use of all important solid materials." Dr. Hollomon hopes that the series can be as comprehensive as possible in order to meet the needs of university students, younger scientists, and engineers as well as those with more experience. Manager of the Metallurgy and Ceramics Research Dept., General Electric Co., Schenectady, Dr. Hollomon is the author of many technical publications in the metallurgical field. He was named in 1955 as one of America's "ten outstanding young men of the year" by the U. S. National Junior Chamber of Commerce. Dr. Hollomon has served *Acta Metallurgica*, since its founding, as secretary-treasurer.

John M. Boxall is associated with Mellanear Works, Williams, Harvey & Co. Ltd., Liverpool, England. He was formerly with National Smelting Co. Ltd., Avonmouth, England.

John M. Parks has resigned from the Research and Engineering Dept., Air Reduction Co., Murray Hill, N. J., to accept a position with Lincoln Electric Co., Cleveland.

L. F. Reinartz, vice president in charge of special operating development, has retired from Armco Steel Corp., Middletown, Ohio. Mr. Reinartz, a graduate of Carnegie Institute of Technology, began his 47-year service to Armco as an open hearth chemist. He was appointed a vice president in 1951. A charter member of AIME National Open Hearth Steel Conference, he served as its chairman. Mr. Reinartz became president of AIME in 1954.

Grover J. Holt, President-Elect of AIME, was the principal speaker at the dedication of the Ores Research Building, Bureau of Mineral Research, Michigan College of Mining & Technology, on August 8th. His address, *Why Be Concerned About Research*, drew attention to the fruits of past research and the need for its continuation. During the ceremonies, Mr. Holt was awarded an honorary Doctor of Engineering degree, the accompanying citation of which praised his "pronounced accomplishments to the mining profession" and his embodiment of "the ideals of service to (his) fellow men and the industrial society in which we live."

John P. Nielsen, metallurgy authority at New York University, is the guest of the Soviet Academy of Sciences, and while in Russia will lecture and attend a scientific conference in Moscow, as well as visit metals institutes and plants in other parts of the Soviet Union. Among Dr. Nielsen's specialties are titanium metallurgy and X-ray diffraction.

J. F. NIELSEN

C. R. Cupp is associated with the Research and Development Laboratories, Canadian Westinghouse Co. Ltd., Hamilton, Ont., Canada, as senior metallurgist in the Metallurgical-Mechanical Section.

L. F. REINARTZ

G. J. HOLT

Hirsch Loevenstein is research director for Harvey Aluminum, Torrance, Calif. He was formerly associated with Harvey Aluminum of U. S. in Salem, Ore.

H. J. Forsyth is director of steel conservation and quality control for Republic Steel Corp., Youngstown.

Leonard Bernstein is metallurgist, Kwikset Locks Inc., Anaheim, Calif.

H. H. Brandt has joined Lacledes-Christy Co., New York, a division of H. K. Porter Co. Inc., as sales engineer.

John N. Ong, Jr., formerly associated with the University of Utah, Salt Lake City, has joined the faculty of Washington University, St. Louis, as an assistant professor in the Mechanical Engineering Dept.

B. T. K. Barry recently resigned from Sherritt Gordon Mines Ltd. to accept a position with the development and special duties group, Metallurgical Div., The Steel Co. of Canada Ltd., Hamilton, Ont., Canada.

Donald H. Désy has joined the staff of Fulmer Research Institute, Stoke Poges, Buckinghamshire, England. He recently received his doctorate in metallurgical engineering science at Columbia University.

Arthur L. Geary, who had been associated with Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N. Y., a division of Union Carbide & Carbon Co., is now at Nuclear Metals Inc., Cambridge, Mass.

Arthur E. Morris is associated with the Dept. of Metallurgy, Purdue University, Lafayette, Ind.

William R. Smith has transferred from Hanford Atomic Products Operation, General Electric Co., Richland, Wash., to the Company's Atomic Power Equipment Dept., San Jose, Calif.

Robert C. Petersen has left Uranium Corp. of America, Salt Lake City, to join Newmont Exploration Ltd., Grass Valley, Calif.

John A. Casner is supervisor of tubular service engineering for Youngstown Sheet and Tube Co., Youngstown.

Among recent appointments at Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N. Y., is that of **John L. Lamont** as personnel administrator. He joined Electromet in 1929 and has been concerned with engineering projects in the steel research group, including work on welding, stainless steels, and high chromium alloys.

Ernest F. Nippes, professor of metallurgy, Rensselaer Polytechnic Institute, Troy, N. Y., is the recipient of ASM's 1956 $2000 teaching award. Dr. Nippes, a graduate of Rensselaer, has been a member of the faculty since 1938. He has also served as a consultant to many industrial firms.

R. J. NEKERVIS

Robert J. Nekervis is at Battelle Memorial Institute, Columbus, Ohio. He had been associated with the Tin Research Institute, New York.

Gordon H. Silver is associated with the control engineering unit at Detroit Controls Corp., Norwood, Mass.

George F. Van Hare, Jr., recently joined the Engineering and Construction Div., American Cyanamid Co., New York, as a project engineer. Mr. Van Hare had been a chemical engineer for Chemical Construction Corp., New York.

William S. Webb is with Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp., Claymont, Del.

Robert J. Teitel is associated with The Dow Chemical Co., Midland, Mich.

William F. Biggs is with The Mazapil Copper Co. Ltd., Saltillo, Coah., Mexico.

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OBITUARIES

Donald Burton Gillies

An Appreciation by
Walter Carroll

Donald B. Gillies (Member 1922) died at his home in Cleveland Heights, Ohio, on September 29. He was born Nov. 4, 1872 at Bruce Mines, Ont. where his father was a miner. The family later moved to the copper country of the northern peninsula of Michigan.

Mr. Gillies graduated from the Mining School, (Michigan College of Mining & Technology) from which he received his degree of mining engineer in 1893. In college he excelled in scholastic work and was a crack football player and track man. As early as 1890 he made the 100 yd dash in 10 seconds. In football he played right half.

Upon graduation he started West, ending up in Butte, Mont. The depression of '93 was at its height, and jobs were few and hard to get. Though a graduate mining engineer, Mr. Gillies got a job "pushing a slag pot," at the Montana Ore Purchasing Co.'s smelter.

He was soon promoted to the drafting room where he did extensive work on concentrator design. But Mr. Gillies' preference did not lie in an office or at a drafting table. He entered the active smelter field, working on reverberatory furnace practice in the production of copper matte, which was followed by a convertor operation in the production of pig copper.

As the depression came to an end he took a position as assistant assayer at the Parrott Silver & Copper Co. About this time Senator W. A. Clark decided to reopen the old copper blast furnace property in the Lost River District, 90 miles by stage from Blackfoot, Idaho. Mr. Gillies was made mining engineer for the W. A. Clark properties in Butte, which embraced both the copper and silver areas.

Promotions followed in quick succession. From mining engineer he was promoted to chief engineer, then to general superintendent and finally to manager of all of the Clark properties. It was while he was serving as manager that the famous Mayflower Mine was discovered and purchased by Mr. Gillies for Senator Clark. The property produced many millions before it ran out.

The desire to see even more of the West still remained active and three years were spent in the gold-silver fields of Tonopah and Goldfield during its most exciting development, when the Montana Tonopah and the Tonopah Extension mines were developed into dividend payers.

Mr. Gillies then turned his interests to Mexico, where in the state

DONALD B. GILLIES

of Chihuahua he was active in mine management, engineering practice, and mine examinations. He accepted management of the Mexican properties of Corrigan, McKinney & Co. of Cleveland, at the solicitation of Price McKinney, then president. These comprised the Rio Tinto Copper and Concheno Mining Co.

In 1910 the Madero Revolution began in Mexico, causing great uncertainty and anxiety among Americans there, and during the next six years existence was constantly tinged with real uncertainty. Pancho Villa ruled the northern states; raids were frequent and costly. In spite of political upheavals the properties he managed operated during the entire period and shipped ore and bullion without interruption or loss, except many hours of sleep.

In 1918 when the revolution ended, Mr. McKinney induced Mr. Gillies to come to Cleveland as vice president in charge of Corrigan, McKinney mining operations in the U. S. and Mexico. In this capacity he developed the Wolfpit & Greasy Creek coal mines at Pike County, Ky. Mr. Gillies held this position until the deaths of Mr. McKinney and Mr. James W. Corrigan, when he was promoted to the presidency in 1932.

Mr. Gillies remained president of Corrigan, McKinney until 1935, when the company merged with Republic Steel Corp., and he joined Republic as vice president.

In 1937 he interested Republic in the possibilities of the Northern Adirondacks and revived the nearly dormant iron ore industry in that area. At his recommendation Republic secured and still operates properties at Port Henry and Lyon Mountain, N. Y. In the late 1940's he investigated and brought to Republic's attention the rich iron ore deposit in Liberia, which the company cooperated in developing. This is perhaps the world's purest ore deposit yielding 68 to 69 pct Fe.

In the last 10 years of his life—a time when most men would have been comfortably retired—he continued to search the world for new ore deposits. His later travels took him to Mexico, Venezuela, Liberia, Peru and Ecuador. On his 75th birthday, he was relieved of the vice presidency of Republic, but continued as mining consultant.

Mr. Gillies, AIME president in 1939, was also a member of the Mining & Metallurgical Society of America, the Montana Society of Engineers, and a trustee and member of the Cleveland Engineering Society.

His civic contributions have also been noteworthy. He was appointed chairman of the River and Harbor Committee, Cleveland Chamber of Commerce. Under his leadership, Cleveland's harbor has been tremendously improved and made accessible to constantly larger vessels. Without this work, Cleveland's iron and steel industry could not have reached its present proportion.

(Continued on page 1687)

Memorial Resolution

DONALD B. GILLIES

WHEREAS, with the passing of Donald B. Gillies at his home in Cleveland Heights, Ohio on September 29, 1956, the Institute has lost one of its most active, loyal, enthusiastic, and honored members; and
WHEREAS, during his many years of membership he took an enthusiastic part in the activities of the Institute. He served as Director in 1940 and 1941 and President in 1939; and
WHEREAS, during his 63 years of professional work his interests were in many phases connected with the mining and extraction of various metals, ferrous and nonferrous; and
WHEREAS, in his progress from a humble laborer to a leader in industry he was the epitome of a true American; and
WHEREAS, he showed deep interest in assisting young men to enter our profession and in recognizing their progress and achievements; therefore, be it
RESOLVED, That the American Institute of Mining, Metallurgical, and Petroleum Engineers records with deep sorrow the passing of one of America's most distinguished engineers, and one of the Institute's best friends and advocates; and be it further
RESOLVED, That this Resolution be included in the minutes of this meeting and that a copy be sent to Mrs. Gillies.

November 16, 1956 — AIME Board of Directors

Mr. Gillies was also a member of the Lake Superior Iron Ore Assn., serving as president from 1947 to 1951, and as Chairman of its Board of Directors until his death.

He was active in the Cleveland Community Fund since 1932, and served on its Board of Trustees. In 1952 and 1953 he was Treasurer of the local chapter of the American Red Cross.

In 1953 he delivered the convocation address at the Michigan College of Mining and Technology, his alma mater, which had awarded him the degree of Doctor of Engineering in 1931. He also received an LL.D. from the Montana School of Mines in 1939.

At 83, Mr. Gillies was an active, valuable member of his company and the community. His contributions to both, as well as to the steel industry and the nation, are of enduring value. Old in years he was energetic, active and an inspiration to all those who were associated with him. Mr. Gillies accomplished in one long lifetime the equivalent of the normal accomplishments of several men. He was active in three fields—nonferrous metals, coal, and iron ore, and made noteworthy contributions in each field, but especially in the field of ferrous metals during the last 20 years.

He was a member of the Union, Kirtland, Chagrin Valley Hunt, Pepper Pike and Mid-Day Tavern Clubs of Cleveland and the Miscowaubik Club of Calumet, Mich. He is survived by his wife, the former Mary Lou Yancey of Rome, Georgia, two daughters and a son, ten grand-children and six-great grandchildren.

Mr. Gillies' friends were legion, including presidents of countries, leaders of industry, on down through the spectrum of life to the corner bootblack. He was widely known as a friend and leader, world-wide contributor to the science of industry, and a wise counselor capable and willing to share his knowledge.

Leonard Peckitt (Legion of Honor Member 1883) died recently. Born in Yorkshire, England, in 1860, he came to America in 1882. Mr. Peckitt was president of Warren Foundry & Pipe Co. He had been associated with Crane Iron Works before its absorption by the Warren Co.

Clair Upthegrove (Member 1920) professor emeritus of metallurgical engineering at the University of Michigan, died at his home in Ann Arbor on October 11. He was born at Central Lake, Mich., on Nov. 30, 1884, and earned a degree in chemical engineering at the University of Michigan, joining the factuly in 1916. Before commencing his teaching career, he was employed as an assistant chemist at the Oliver Mining Co. of Ironwood, Mich., and metallurgist for the Detroit Copper & Brass Rolling Mills. During World War I, he was an ordnance officer in the Army. An outstanding teacher, Professor Upthegrove also made valuable contributions to the field of metallurgy of nonferrous metals, scaling and decarbonization of steels, and diffusion in metals. His articles appeared in many professional journals. In addition to the AIME, Prof. Upthegrove served in the ASM, ASTM, the American Foundrymen's Assn., and the Society for Promotion of Engineering Education.

NECROLOGY

Date Elected	Name	Date of Death
1926	W. B. Coleman	Sept. 30, 1956
1935	Frank Eicheiberger	Oct. 21, 1956
1922	Donald B. Gillies	Sept. 29, 1956
1949	Malcolm Glen	Unknown
1938	J. Spencer Hollings	June 1956
1883	Arthur H. Keller Legion of Honor	Unknown
1929	F. H. Kihlstedt	Oct. 19, 1956
1901	V. F. Stanley Low Legion of Honor	Unknown
1919	H. E. Nyberg	Oct. 18, 1956
1914	J. C. Pickering	Oct. 10, 1956
1940	James H. Ratliff	Sept. 20, 1956
1955	Joseph H. Show	Unknown
1920	Clair Upthegrove	Oct. 11, 1956
1948	R. G. Wheaiton	Unknown
1903	William Wraith Legion of Honor	Oct. 10, 1956

MEMBERSHIP

Proposed for Membership
Metals Branch, AIME

Total AIME membership on Oct. 31, 1956, was 25,844; in addition 2,940 Student Associates were enrolled.

ADMISSIONS COMMITTEE

R. B. Caples, Chairman; F. A. Ayer, Vice-Chairman; A. C. Brinker, R. H. Dickson, C. R. Dodson, R. B. Fulton, T. D. Jones, F. W. Hanson, Sidney Rolle, F. T. Sisco, O. B. J. Fraser, F. W. McQuiston, Jr., A. R. Lytle, L. P. Warriner.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Floyd R. Anderson, Denver
Louis C. Beale, Jr., Columbus, Ohio
Samuel J. Beckman, Pittsburgh
Charles Choate, East St. Louis, Ill.
J. C. Douglas, New York
J. E. Elliott, Steubenville, Ohio
V. E. Elliott, Hobart, Ind.
George Havas, Oakland, Calif.
Edward Heinzelman, Jr., Palisades Park, N. J.
James C. Kenney, Indianapolis
Howard Lanier, Magna, Utah
Thomas H. LeCompte, Newfield, N. J.
James J. Lombardo, Bridgeville, Pa.
M. A. Luck, Copperciiff, Ont., Canada
R. F. Obenchain, Sparrows Point
Edward Pesout, McGill, Nev.
Stanton L. Reese, Hamilton, Ohio
Benjamin W. Roberts, Jr., Schenectady
Lars Ryasdal, Columbia Falls, Mont.
Harry D. Shephard, Pittsburgh
Chester T. Sims, Columbus, Ohio
John R. Slater, Washington, Pa.
S. S. Sotelo, La Oroya, Peru
L. H. Walker, Louisville
C. W. Weber, Ballston Lake, N. Y.
Robert C. Williams, Columbus, Ohio

Associates

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Earl B. Blasch, Cincinnati
Carl A. Kimball, Kellogg, Idaho
Christian G. Rosenbohm, Bartonville, Ill.
D. B. Simonson, New York
Emilian Strauss, Montreal
Franklin Witmer, Woodville, Ohio

Juniors

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W. Bruce Aufderhaar, Warren, Ohio
George R. Berry, Pittsburgh
James F. Black, Bayside, N. Y.
Edward E. Borders, Plainfield, N. J.
Vijay K. Chandhok, Pittsburgh
F. Richard Cortez, Pittsburgh
David R. Chipman, Watertown, Mass.
John F. Endler, Jr., Torrington, Conn.
David Goldstein, Pittsburgh
Kenneth C. Haggarty, Union, N. J.
Frank Walter Heck, Fort Lee, N. J.
Marvin Herman, Folcroft, Pa.
Robert V. Hill, Glenn Ferris, W. Va.
Allen L. Klibanoff, Warren, Ohio
Andrew F. Kravic, Far Rockaway, N. Y.
Richard C. Lacerte, Pittsburgh
Lawrence W. Lindquist, Tacoma, Wash.
James E. Matthews, Tacoma, Wash.
James G. Morris, Midland, Mich.
Alfred Wayne Naumann, Buffalo
James Owen, Jr., Plainfield, N. J.
James Pappas, Irwin, Pa.
Alfred E. Riccardo, Scotch Plains, N. J.
Grant E. Spangler, Philadelphia
Richard J. Taglang, Pittsburgh
Raymond Totah, Kellogg, Idaho
John L. Walter, Scotia, N. Y.
Frederic E. Weil, Redwood City, Calif.
Joseph M. Wentzell, Warren, Ohio

CHANGE OF STATUS

Associate to Member

R. L. Fullman, Schenectady
Anthony J. Kroha, Salt Lake City

REINSTATEMENT

Members

Paul S. Kingsley, Richland, Wash.
Bruce B. LaFollette, Denver
Hamnett P. Munger, Fayetteville, N. Y.
Royale J. Stevens, Salt Lake City

REINSTATEMENT—CHANGE OF STATUS

Student to Member

William C. Greenleaf, Chappaqua, N. Y.
Robert J. King, Pittsburgh
H. B. Parfet, Jr., Chicago
Howard C. Parker, Linthicum Heights, Md.

Student to Junior

Richard James Gennone, Richmond, Va.

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COMING EVENTS

Dec. 9-12, AIChE, annual meeting, Statler Hotel, Boston.

Jan. 6, 1957, AIME, NOHC Western Local Section, Rodger Young Auditorium, Los Angeles.

Jan. 7, AIME, Boston Local Section. Speaker: W. D. Manly, Oak Ridge National Laboratory, on nuclear metallurgy.

Jan. 17-18, EJC, annual meeting, Statler Hotel, New York.

Jan. 22, AIME, Connecticut Local Section. Speaker: D. K. Compton, Chase Brass and Copper Co.; subject: *New Developments of Copper Alloys.* New Haven, Conn.

Feb. 1, AIME, NOHC Southwestern Local Section, technical meeting.

Feb. 24-28, AIME Annual Meeting, Roosevelt and Jung Hotels, New Orleans.

Mar. 10-13, AIChE, Greenbrier Hotel, White Sulphur Springs, W. Va.

Mar. 10-16, EJC Second Nuclear Engineering and Science Congress, Convention Hall, Philadelphia.

Mar. 13, AIME, NOHC Western Local Section, Rodger Young Auditorium, Los Angeles.

Mar. 13, AIME, NOHC Chicago Local Section, annual all-day meeting, Del Prado Hotel, Chicago.

Mar. 25-29, ASM And Others, Tenth Western Metal Exposition and Congress, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles.

Mar. 26, AIME, Connecticut Local Section. Speaker: P. C. Rossin, Universal-Cyclops Steel Corp.; subject: *Metallurgical Aspects of Vacuum.* Waterbury, Conn.

April 5, 6, AIME, Pacific Southwest Mineral Industry Conference. Sponsor: Nevada Local Section; cosponsors: San Francisco and Southern California Local Sections. Reno.

Apr. 8-10, AIME National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conferences, Penn-Sheraton Hotel, Pittsburgh.

Apr. 11-13, AIME, Pacific Northwest Regional Conference, Multnomah Hotel, Portland, Ore.

Apr. 16-17, AIME Regional Conference on High Temperature Alloys, Hotel Carter, Cleveland.

May 5-9, American Ceramic Soc., annual meeting, Statler Hotel, Dallas.

May 6, AIME, NOHC Chicago Local Section, spring meeting, Phil Smidt's Restaurant, Chicago.

May 12-16, Electrochemical Soc., Statler Hotel, Washington, D. C.

May 28-29, AIME, Reactive Metals Conference. Mining Branch sessions on May 28; Metals Branch sessions on May 28, 29. Ambassador Hotel, Los Angeles.

June 8, AIME, NOHC Southern Ohio Local Section, annual golf party, Middletown, Ohio.

June 23-28, ASTM, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Oct. 6-9, AIME, Petroleum Branch, Dallas.

Oct. 9-11, Joint Solid Fuels Conference, ASME-AIME Coal Div., Chateau Frontenac, Quebec.

Oct. 18, AIME, NOHC Southern Ohio Local Section, annual meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Oct. 30-Nov. 1, AIME Rocky Mountain Minerals Conference, Denver.

Nov. 4-6, AIME, IMD Fall Meeting, Morrison Hotel, Chicago.

Nov. 13, AIME, NOHC Buffalo Local Section, annual meeting, Hamilton, Ont., Canada.

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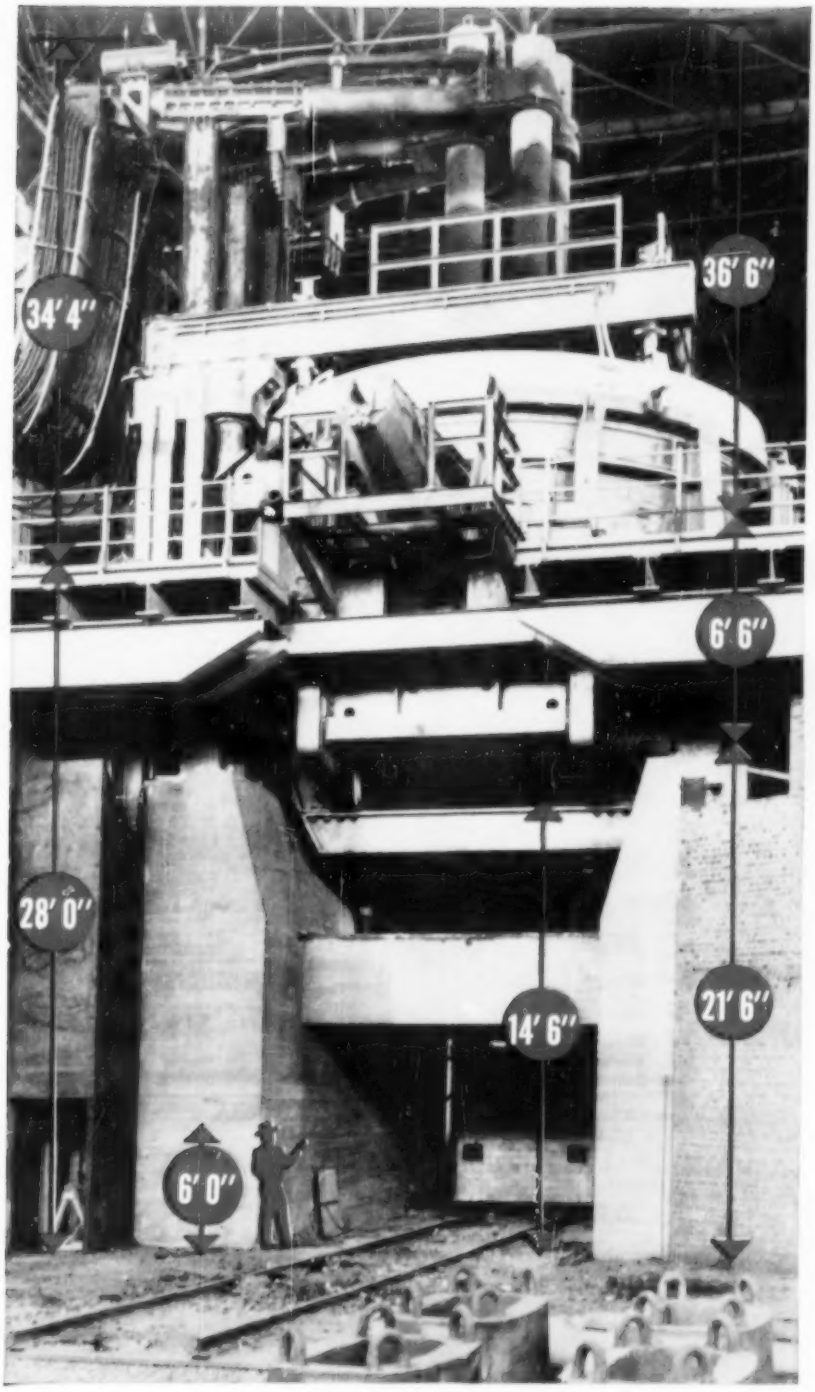

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DATA ON VOLMEX 81 . . .

HOW VOLMEX® 81

performs as a high volatile ingot mold coating when applied . . .

(1) Wet (2) Dry (3) At varying ingot mold temperatures

VOLMEX 81 is a highly volatile ingot mold coating which has been tested and adopted by a number of steel plants. The charts below are based on actual data obtained during such trial runs. Because of the differing practices employed by various companies, we have included several variables. First, because VOLMEX 81 can be applied either dry or with water as the carrier (spraying, swabbing or dipping are all practical), we have presented test figures on its use, both wet and dry. Second, we have included data on a range of ingot mold temperatures from 100°F. to 700°F., and third, we offer for comparison the results of a one-hour and a three-hour time-at-mold temperatures. No matter what method of application was used, VOLMEX 81 was found to repel metal splashes effectively before they could solidify and cling to the mold wall. At the same time, enough of the graphite-base coating was left at the metal/mold interface to keep the main body of the pour from clinging when it reached the point of splash, thus reducing surface defects. For wet application, VOLMEX 81 is easily stirred into suspension and remains in that state for hours without re-agitation.

VOLMEX 81 is the most volatile of the United States Graphite Company ingot mold washes. Others, in order of their volatility are: 90-B (non-volatile), MEX (very little volatility), and VOLMEX (volatile, but less so than VOLMEX 81). Write us for more extensive details or our engineering staff is available for on-the-spot assistance. Mold spray and mixing equipment are ready for your use in tests you may want to arrange.

Table I **Volatility of VOLMEX 81 Ingot Mold Wash**

Mold Coating Volatility Test—VOLMEX 81 Water Application 2.75 lbs. powder/gal. water—Period—1 Hour at	Temperature 300°F.	500°F.	700°F.
% loss after heating for 1 hour	74.3	73.9	75.4
% loss on ignition at 1900°F. after 1 hour at specified temperature	16.1	14.4	11.3
Total percent volatile matter	90.4	88.3	86.7

Table II

Mold Coating Volatility Test—VOLMEX 81 Dry Application—Period—1 Hour at	Temperature 100°F.	300°F.	500°F.	700°F.
% loss after heating for 1 hour	0.1	0.8	0.9	2.8
% loss on ignition at 1900°F. after 1 hour at specified temperature	60.8	60.4	59.7	56.5
Total percent volatile matter	60.9	61.2	60.6	59.3

Table III

Mold Coating Volatility Test—VOLMEX 81 Dry Application—Period—3 Hours at	Temperature 100°F.	300°F.	500°F.	700°F.
% loss after heating for 3 hours	0.1	0.8	1.1	4.5
% loss on ignition at 1900°F. after 3 hours at specified temperature	60.6	59.6	59.7	53.1
Total percent volatile matter	60.7	60.4	60.8	57.6

You will note in the first chart which is the wet application, that the loss is all of the water contained plus a slight amount of the remaining volatile. Since on a weight basis, the powder is about ¼ of the make-up, if you will multiply the percent loss figures at 1900°F. by four, you will get an idea of the amount of volatile which would be present for loss during the pouring operation.

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